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NAVAL AVIATION

A Text Book for the
Instruction of Midshipmen in the Department of Seamanship,
U. S. Naval Academy

Compiled by
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Aviation
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PREFACE TO FIRST EDITION

Much of interest has been written on the subject of Naval Aviation—its problems, its policy, its strategy, and its tactics.

The object has been to assemble into one volume that portion of this material of interest to the midshipman and to the naval officer afloat, that it may be readily available. Everything of a technical nature has been purposely excluded.

In collecting the data the compiler has made full use of lectures before the War College, of published articles, and of the *Pensacola Manual*. Generous assistance has been given by the Bureau of Aeronautics and the Army Air Service.

To those who have thus liberally given their assistance the compiler wishes to express his appreciation.

WILLIAM W. WARLICK.

Annapolis, Md.
15 December, 1924.

PREFACE TO REVISED EDITION

The science of aviation is advancing at such a rapid rate that any aviation textbook is hardly off the press before it is out of date. In this revision, therefore, besides excluding as much technical matter as possible, effort has been made to handle the subject matter in such general terms that what is said will hold as true two years hence as today.

The reviser freely admits wholesale plagiarism from all sources available, but unproved opinions have been avoided.

Appreciation is expressed to Rear Admiral W. A. Moffett, U. S. Navy, and officers of the Bureau of Aeronautics for valuable assistance.

V. F. GRANT.

Annapolis, Md.
9 January, 1929

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Courtesy Bureau of Aeronautics, Navy Department.

ELY LANDING ON THE AIRPLANE PLATFORM OF THE U.S.S. "PENNSYLVANIA," SAN FRANCISCO. JAN. 18, 1911. THE PLATFORM WAS 32 BY 127 FEET.

CHAPTER I

HISTORY OF NAVAL AVIATION

THE BEGINNING OF AVIATION

Although a large number of experimenters gave their attention to the problem of mechanical flight previous to the last decade of the nineteenth century, nothing practical was achieved prior to that time. But with the perfection of the steam engine and the development of the internal-combustion engine, there came inducement to sound experimentation bringing forth such well known scientists and inventors as Lilienthal, Maxim, Langley, and the Wright brothers.

Otto Lilienthal, a German, made the first successful flight in a man-carrying glider in 1891. This glider was a bird shaped apparatus made of willow wood with waxed sheeting. It used arched or cambered wings, weighed 40 pounds, and had a wing spread of 107 square feet. There were no control levers and his only method of steering was to shift the balance of the machine by swinging his legs one way or the other. Lilienthal continued his man-carrying experiments with gliders and soon thereafter developed tail surfaces for steering vertically and horizontally. He lacked the third rudder or aileron control, however, and was still dependent on the shift of body weight for preserving the lateral balance. Having executed nearly two thousand flights with several monoplane gliders, Lilienthal in 1895 built a biplane glider. He found this much easier to control and now thought he had sufficiently acquired the art of flying to justify his undertaking the next and more difficult art of imitating the rowing flight of birds. He therefore had constructed a 90-pound engine of 2.5 horse-power, to actuate the wings of his glider but before this motor was ready for use, he was killed while making a long glide on August 9, 1896. Lilienthal gave a powerful and permanent impulse to aviation both by his writings and by his practical experience in the air. He first showed quantitatively the advantage of cambered wings and proved the effectiveness of the vertical and horizontal rudders. He was the father of the aerial glider and he intended to undertake the problem of a power-driven flying machine at the time of his accidental death.

Sir Hiram Maxim was an Englishman who in 1893 built a gigantic airplane powered with a steam engine driving two large propellers. It was a multiplane weighing three and one-half tons and having a span of 126 feet and a wing area of 5,500 square feet. Its propelling plant comprised a naphtha tubular boiler and a compound steam engine of 350 horse-power actuating twin screws 17 feet 10 inches in diameter. The airplane was to be steered by vertical and horizontal rudders and its lateral stability was to be secured by side planes set at a dihedral angle. The machine was mounted on a platform car running along a track half a mile in length. Above the rails of this track were guard rails to prevent the airplane from rising more than three inches during the preliminary tests. Many runs along the track were made to test the working of this huge

apparatus before trusting it to launch forth in free flight. During these runs the machine frequently lifted clear of the lower track and flew forward resting against the guard rails above. Finally, on a gusty day so much lift was obtained that these holding-down rails gave way, whereupon the machine rose into the air with Maxim and his assistant, and then toppled over on the soft earth, and was wrecked. Here Maxim discontinued his experiments for lack of funds after having demonstrated that a large weight can be carried in dynamic flight, but having failed to prove the feasibility of controlling an airplane in launching, in free flight, and in landing.

Professor S. P. Langley, of the Smithsonian Institution, was the first person to construct an airplane possessing inherent stability. On May 6, 1896, an airplane model equipped with a steam engine was successfully launched and flown, making three and a quarter turns. Tandem wings and a horizontal tail surface provided longitudinal stability, a large wing dihedral provided lateral stability, and a vertical tail surface provided a degree of directional stability. This model weighed thirty pounds, measured sixteen feet in length, and had a wing span of thirteen feet. The engine developed between 1 and 1.5 horse-power. As a result of this success, the Board of Ordnance and Fortifications of the War Department appropriated $50,000 to enable Langley to build a man-carrying flying machine. He first tested a gasoline-driven model, having one-fourth the linear dimensions of his man-carrying machine. This model was successfully flown on August 8, 1903, and proved to be very satisfactory in all its dynamic features. Langley's man-carrying airplane was nearly a duplicate on a four-fold scale of the gasoline model. There was, accordingly, every reason to expect that, weighted and launched like the model, it would fly with the same inherent equilibrium and speed, even if left to govern itself. Having in addition a living pilot provided with rudders for steering and balancing, together with adequate fuel for a considerable journey, it seemed to promise still better results than the model. The whole machine weighed 830 pounds, including the pilot, and had a wing area of 1,040 square feet. The gasoline, water-cooled engine weighed, without accessories, 125 pounds, and developed 52.4 horse-power in actual test at a speed of 930 revolutions per minute. Two attempts at trial flights were made with this machine, the first on September 7, 1903, and the second on December 8, 1903, but both attempts at launching were unsuccessful due to a minor defect in the launching apparatus.

Thus this carefully designed machine never had a chance, even for a moment, to exhibit its powers of sustentation and balance in normal flight. Langley now abandoned his experiments for want of funds to continue them and stowed away the machine in the Smithsonian Institution with its frame and engine still intact, the wings having been injured in the unsuccessful attempt at launching. If this machine had performed as successfully in 1903 as it actually did in 1914 after being rebuilt by the Curtiss Company, Langley would have antedated the first successful powered flight of the Wright brothers.

Wilbur and Orville Wright of Dayton, Ohio, attacked the problem of mechanical flight by experimenting with gliders. Their first glider was completed and successfully flown at Kitty Hawk, N.C., in the summer of 1900. In this glider, as in all their early machines, sled runners, fixed under the machine, were used

for launching and landing. With a wing surface of 165 square feet, they were able to glide down a slope of ten degrees at a speed of about thirty miles per hour. The machine was maintained in lateral stability by wing warping. The glider used in the summer of 1901 was modeled after that of the previous year, but was larger. It had a wing area of 308 square feet and weighed 108 pounds. With this glider a considerable number of glides were made, of various lengths up to 400 feet. In 1902 a third glider was constructed which was larger and showed greater efficiency than either of its predecessors, its normal angle of descent being 7 degrees or less. With this machine some seventy glides were made and it successfully performed all the evolutions necessary for flight. The Wright brothers were now ready to apply power to a machine to drive it through the air and gain flotation by speed of motion. A power machine equipped with a sixteen horse-power gasoline engine was constructed in 1903. This machine was a pusher weighing 750 pounds and possessed warping wings, a warping elevator in front, and a double rudder in rear for control purposes. On December 17, 1903, Orville Wright made the first successful man-carrying power-driven airplane flight in the history of aviation with this machine at Kitty Hawk, North Carolina. Four flights were made on this eventful day, the first flight lasting twelve seconds, the next two a little more, and the fourth lasting 59 seconds and covering a distance of 852 feet.

The Wright brothers continued their experiments during the next two years with increasing success. During the season of 1904 on a field near Dayton, 105 flights were made and the first complete circle was flown. In 1905 the flights were resumed with a new machine embodying some changes dictated by experience, particularly in the method of control. On September 26, a flight of 11 miles was achieved. This was followed, within the next nine days, by flights of 12, 15, 21, and 24 miles at a speed of about 38 miles per hour. After this the Wright brothers ceased flying for two years and the machine was dismantled to preserve secret its mode of construction till the patents could be disposed of.

The first public demonstration of a man-carrying, power flight was made by Santos-Dumont in France on August 22, 1906, flying thirty-six feet at a velocity of 23 miles per hour. The machine which he used was equipped with an 8-cylinder Antoinette gasoline engine developing 50 horse-power, had a wing surface of 650 square feet, and weighed, including pilot, 645 pounds. In an exhibition flight on November 12 Santos-Dumont succeeded in making a flight of 723 feet, thus gaining the prize of 1,500 francs offered by the Aero Club of France for the first person who should fly 100 meters. Although Santos-Dumont was not the first to fly, he was the first airplane inventor to give his art to the world, as the general public never had any concrete idea of the machine of the Wrights' until their public flights in 1908. Since Santos-Dumont's public exhibitions of the airplane in 1906, the progress of the art has been steady, rapid, and convincing.

The period from 1906 to 1914 may be called the period of the inventors in the history of aviation. The art of aircraft design and construction had little scientific or engineering basis. Stresses in flight were largely unknown and the aerodynamics of balance and control were dimly understood. The theory of stability was quite unappreciated and wing sections in use were inefficient. How-

ever, very active experimenting was being done all over the world and very important patents were being taken out.

PRE-WAR NAVAL AVIATION

The Navy first investigated the possibilities of aviation for naval purposes in 1908 when Lieutenant G. C. Sweet and Naval Constructor McIntee were detailed as observers for the test of the Wright plane at Fort Myer, Va. Lieutenant Sweet endeavored to stimulate interest in the subject of aviation and suggested the use of pontoons in his report to the Navy Department but no action was taken thereon. In 1910, Captain W. I. Chambers, U. S. Navy, who was assistant to the aide for material in the Bureau of Equipment, attended the aviation meets at Belmont Park, N.Y., and at Halethorpe, near Baltimore, as an official observer. Appreciating the potential value of the airplane in naval warfare, Captain Chambers endeavored to arrange for a flight off a United States man-of-war. The Curtiss Company agreed to try it. The necessary arrangements were thereupon made by Captain Chambers and on November 14, 1910, the Curtiss representative, Mr. Eugene Ely, successfully flew a 50-h.p. Curtiss landplane from a platform hastily built on the bow of the U.S.S. *Birmingham* at Hampton Roads, Va.

Following this successful experiment, Mr. Glenn H. Curtiss of the Curtiss Company agreed to instruct several naval officers free of charge as no money had as yet been appropriated by Congress for the development of naval aviation, and Lieutenant T. G. Ellyson, U. S. Navy, was sent to the Curtiss Camp at San Diego, Calif., in December, 1910. On January 18, Mr. Ely, then attached to the Curtiss Camp at San Diego, made a successful landing with an airplane on the deck of the U.S.S. *Pennsylvania* lying in San Francisco harbor and the next day he flew this plane from the deck on which he had landed. During this same month, Mr. Glenn Curtiss and Lieutenant Ellyson perfected a hydro-airplane attachment for airplanes. On January 26, 1911, Mr. Curtiss flew from the water at his San Diego base, landed alongside the U.S.S. *Pennsylvania,* was hoisted aboard ship, subsequently hoisted out again, and flew back to his camp. This performance together with the previous feats of Mr. Ely gave a very decided impetus to the development of naval aviation not only in this country but in all the leading countries of the world.

As a result of Captain Chambers' reports and recommendations on aviation, the first aviation appropriation of $25,000 was included in the 1911-1912 Naval Appropriation Act. On March 13, 1911, Captain Chambers received orders assigning him to the Bureau of Navigation and directing him to devote his efforts exclusively to aviation and to the coördination of the aeronautical work of the various bureaus. This officer struggled with the many difficulties which always present themselves to those to whom fate assigns the difficult task of injecting new ideas and a new activity into a staid and elderly organization. The Navy as a whole was not interested and Captain Chambers worked alone and unassisted to build up a naval aviation establishment.

Early in 1911, Lieutenant John Rodgers, U. S. Navy, Lieutenant John Towers, U. S. Navy, and Ensign V. D. Herbster, U. S. Navy, were ordered to the Curtiss and Wright Companies for instruction in the art of flying. Two Curtiss planes and one Wright plane were purchased and in the summer of 1911 the first

naval aviation unit was organized and an aviation camp established at Greenbury Point on government land near Annapolis, Md. In the summer of 1911 the first naval seaplane was flown off a suspended cable, Lieutenant Ellyson acting as pilot. This camp was transferred to San Diego on land adjoining the Curtiss Camp during the winter of 1911-1912 and moved back to Annapolis the following summer where tent hangars were set up fronting the Severn River.

The first notable flight by a naval aviator was accomplished in the autumn of 1911 by Lieutenant John Rodgers who flew from Annapolis to Washington and then to College Park, Md., from which place he later returned to Annapolis via Baltimore and Havre de Grace. Lieutenants Ellyson and Towers made a memorable record flight over the waters of Chesapeake Bay from Annapolis to Fortress Monroe, and return, also in the autumn of 1911. In the next year Lieutenant Towers established a new world's endurance record for seaplanes by remaining in the air six hours and ten minutes. During the year 1912, the following officers were ordered to the naval aviation camp for flying instruction: Naval Constructor H. C. Richardson to San Diego, Lieutenant (jg) G. Chevalier, Lieutenant (jg) P. N. L. Bellinger, Lieutenant (jg) W. D. Billingsley, First Lieutenant A. A. Cunningham, U. S. Marine Corps, and First Lieutenant B. L. Smith, U. S. Marine Corps.

The year 1912 saw the invention of the catapult, a distinctly American achievement. The first catapult was designed at the Naval Gun factory, Washington, D.C., under the supervision of Captain Chambers. The first shot that was attempted, with Lieutenant Ellyson as pilot of the plane, proved unsuccessful. The redesign of the catapult was assigned to Naval Constructor Richardson and Lieutenant Ellyson was successfully catapulted from this second catapult on October 12, 1912. This extraordinary feat was accomplished from a float at Washington Navy Yard.

Another important naval aviation accomplishment which occurred in 1912 was the construction of the U. S. Navy Aerodynamical Laboratory at the Washington Navy Yard.

In January, 1913, the naval aviation detachment was transported by a Navy collier to Guantanamo for its first operation with the fleet. The Cuban camp was commanded by Lieutenant Towers, subject to orders from the commander in chief of the fleet. Numerous interesting and practical tests were made of the employment of planes in coöperation with ships and many of the fleet officers became more or less familiar with aviation. At this time several notable flights were made along the Cuban coast and the usefulness of aircraft as scouts in discovering the approach of a distant fleet, and in detecting mine fields and submarines was amply and practically demonstrated. With the return of the fleet to the United States after the winter maneuvers, the aviation detachment was transferred back to Annapolis and continued under command of Lieutenant Towers.

In June, 1913, Lieutenant Bellinger hung up a world's seaplane record for altitude by ascending to 6,200 feet in forty-five minutes in a Curtiss seaplane. First Lieutenant B. L. Smith, U. S. Marine Corps, by starting from the water, alighting on the land, and then returning to the water, made the first successful flight in an amphibian or combined land and water aircraft in the summer of 1913.

In October, 1913, a board of aeronautics was appointed by the Secretary of the Navy to report on the needs of a suitable aeronautical organization and establishment for the Navy. Captain W. I. Chambers was made chairman of the board and a policy of development was outlined. One of the most important recommendations of this board was for the establishment of an aviation station at Pensacola, Fla. This recommendation was approved and in January, 1914, the first United States Navy air station was established on the site of the abandoned navy yard at that place. At the same time the Annapolis aviation camp was broken up and all aviation personnel and equipment transferred to the U.S.S. *Mississippi* which was ordered to Pensacola and turned over to naval aviation in order that aviation might keep in touch with ships. Lieutenant Commander Henry C. Mustin was assigned to aviation and become the first commanding officer of the Pensacola Air Station.

The year 1914 saw the first employment of naval aviation in active service. When the Atlantic Fleet was ordered to Mexican waters in April, 1914, in connection with the occupation of Vera Cruz, a naval aviation section, consisting of two airplanes completely manned and equipped, was attached to the U.S.S. *Mississippi* which was sent to Vera Cruz, and another was attached to the U.S.S. *Birmingham* which was sent to Tampico. The two airplanes at Vera Cruz were used continually, and although these planes were not fitted for land work, for forty-three days they did considerable scouting over the trenches protecting the city of Vera Cruz. To every call made upon them, the naval aviators attached to the *Mississippi* made ready and cheerful response and their scout work in the air was of much value in the combined Army and Navy operations at Vera Cruz. In the summer of 1914, the *Mississippi* was relieved by the U.S.S. *North Carolina* as the naval aviation ship, the government having sold the former ship to Greece.

In June, 1914, the Navy Department ordered Lieutenant Towers to Hammondsport, N.Y., for duty in connection with the construction and proposed flight to Europe of the twin-engined seaplane *America*, with the understanding that he would be permitted to participate in that flight if success seemed feasible. The outbreak of war interrupted the project. The *America* marked the beginning of big boat development. At this point naval aviation suffered a serious set back. The war broke out and the *North Carolina* with its complement of aviation officers and men, augmented by other naval personnel, was ordered to Europe. The ship remained in Europe until the summer of 1915, performing various duties in connection with the relief of Americans there. In addition, Lieutenant Towers was ordered as Assistant Naval Attaché, London, and Lieutenant Herbster and Lieutenant B. L. Smith to Berlin and Paris, respectively, for the same duties. Work at Pensacola was brought practically to a standstill for many months.

During 1915 the first Navy-designed seaplane was built at the Washington Navy Yard. This plane was designed by Naval Constructor Richardson. On April 20, 1915, the Navy bought its first airship, the *D-1*, from the Connecticut Aircraft Company of New Haven, Conn. In this year Lieutenant Saufley ascended to an altitude of 14,500 feet in a Curtiss seaplane and shortly afterwards made an endurance record of eight hours and twenty minutes in the same type

of plane. Another notable event of 1915 was the first catapult flight from a ship underway which was made from the U.S.S. *North Carolina* by Captain H. C. Mustin.

In the early part of 1916, the aviation ship, the U.S.S. *North Carolina,* with five planes aboard, operated with the fleet during the winter maneuvers based on Guantanamo. An attempt was made in 1916 to establish a combined experimental station for the Army, the Navy, and the National Advisory Committee for Aeronautics at Langley Field, Va., but as this field was unsuitable for naval purposes because of lack of deep water access for ships, the project was abandoned.

Naval aviation from the very beginning has developed with the primary idea of its application to the fleet. Shortly after the first successful flight by the Wright brothers, naval officers began the pioneer work along this line. It is a striking fact that the very first effort of these pioneers was directed toward coöperation with the fleet. As examples, we have Ely's take-off from the deck of the *Birmingham* in November, 1910, and his landing on the deck of the *Pennsylvania* in January, 1911, the operation of naval aviation with the fleet at Guantanamo in 1913, the operations in Vera Cruz in 1914, and many other similar incidents. It is with this fundamental principle in view that all naval aviation development has gone steadily forward.

WORLD WAR NAVAL AVIATION

Naval aviation in the World War was of necessity a deviation from the policy of application to fleet needs. It will be remembered that at the time of our entry, the submarine menace was the greatest danger. Naval aviation therefore concentrated on this problem. Another very great naval activity was the convoy and escort of troop transport and supply vessels.

At the outbreak of hostilities the number of trained aviators or of persons familiar in any way with naval aviation was small. The early training of pilots and mechanics had covered only the flying of aircraft, without particular attention to the requirements of aerial combat or other warlike operations. For the purposes of war, it immediately became necessary to obtain numerous trained crews composed of pilots, machine gunners, and observers, in order to operate successfully the bombs, machine guns, and radio making up the equipment of aircraft. In addition, a very large force of so-called trained ground personnel was required, and the enrollment and training of the tremendous numbers of officers and men required was in itself a task of stupendous magnitude.

The strength of the commissioned and enlisted personnel of the Navy assigned to aviation duty on April 6, 1917, and the same data as of November 11, 1918, appears in the following table:

	Apr. 6, 1917	*Nov. 11, 1918*
Officers (naval aviators)	38	1,656
Officers (student naval aviators)	0	288
Officers (ground)	0	891
Student officers (training for commission)	0	3,881
Total officer personnel	38	6,716

Courtesy Bureau of Aeronautics, Navy Department.

FLIGHT BEACH, NAVAL AIR STATION, PENSACOLA, FLA., MARCH, 1914

	Apr. 6, 1917	*Nov. 11, 1918*
Men (aviation ratings)	163	21,951
Men (aviation duty ratings)	0	8,742
Total enlisted personnel	163	30,693
Total personnel	201	37,409

The following number of officers and enlisted men were sent overseas during the period of the war:

Officers	1,237
Enlisted men (aviation ratings)	8,215
Enlisted men (aviation duty, miscellaneous ratings)	8,072
Total personnel sent abroad	17,524

The total naval aviation fatalities during the World War amounted to:

	Overseas	*At Home*
Officers	36	38
Enlisted men	86	48
Total	122	86

When the training of personnel was begun it was soon found necessary to divide the training into three phases, namely, ground school, elementary flight training, and advanced ground school and flight training. The first ground school was established at the Massachusetts Institute of Technology in September, 1917. The aim was twofold: (1) to give students academic instruction in aeronautical matters, and (2) to inculcate in them the conception of strict military discipline.

Elementary flight training was carried on at Bay Shore, Miami, Key West, and San Diego. Additional elementary schools were contemplated but the sudden conclusion of hostilities eliminated the need of them. At these elementary training stations the student flying officer was taught to fly. His instruction in a few ground school subjects was also continued. The advanced training station was located at Pensacola, Fla., and here the student naval aviators were taught gunnery, bombing, navigation, and big boat flying.

To provide officer personnel to discharge other than flying duties, it became necessary to establish a class known as "ground officers," which included ordnance, communication (intelligence), navigation, aerography, and administration officers. Such ground officers were at first trained simply by the expedient of giving them the pilot's course at Massachusetts Institute of Technology and then detailing them to flight stations to become familiar with actual aviation work.

For the training of aviation mechanics, elementary trade schools were established at convenient points throughout the country and an advanced training school was established at Great Lakes, Ill. Aviation mechanics, who had been selected at the various elementary schools because of their special ability and qualifications, were sent to the Great Lakes school for advanced instruction. This school soon became one of the largest and most successful manual training schools in the country.

In addition to the overseas patrol stations, home patrol stations were established at strategic points along the Atlantic seaboard from North Sydney,

Nova Scotia, to Key West, Fla., and also to Coco Solo in the Canal Zone. Regular daily patrols were carried out by these stations and aircraft were detailed from these points to accompany all important convoys. During the year 1918, U. S. Navy airplanes flew a total of 40,883 hours on patrol duty in home waters. Patrols during the last three months of the war covered 1,305,000 nautical miles. Lighter-than-air aircraft patrols in home waters flew a total of 5,145 hours.

Curtiss had designed a seaplane for Mr. Wanamaker in which it was intended to cross the Atlantic, the *America* mentioned earlier in the chapter. The hull of this incompleted plane was still in the Curtiss plant. The Liberty engine was about to be produced. Consequently it was decided to assemble a plane using the Curtiss hull, the Liberty engine, and the wings from the *R*-type seaplane—the best then in use. This assembly would make a plane that could be produced in a short time, and although its performance might not be entirely satisfactory it would give the Navy something to work with until a better one could be designed. After a few trials two sections were added to increase the wing surface and thereby the performance. The result was the *HS-2*-type plane, of which many were built.

Curtiss, in the meantime, was busy developing a two-engine plane—the *H-16*, the performance of which was good.

The British air force had been working along the same lines and had arrived at very much the same conclusion. The British plane, the *F-5-L*, was a bit larger than the *H-16* and had a better military performance. The two planes were so similar that the contracts were changed to call for *F-5-L*'s instead of the *H-16*.

As soon as active part was taken in the war, naval aviation established seaplane patrols at points in the British Isles, France, and Italy. The most active of these stations were at Dunkirk and Killingholm. The personnel of both these stations performed excellent service. Dunkirk was repeatedly subjected to enemy bombing raids. The personnel lived in dugouts. At times it was necessary for the planes to be taken from the hangars and scattered to avoid destruction. From Killingholm a patrol was maintained over the Dogger Bank almost continuously.

In the spring of 1918 personnel that could be spared was sent to France and organized into the Northern Bombing Group. The mission of this new organization was the destruction of enemy bases devoted to submarine activities. But it was too late. The fates of war prevented these naval activities from reaping their just reward. The seaplane patrols were hardly more than well started when submarine activities were suspended. The German evacuation of Zeebrugge prevented the Northern Bombing Group from ever rendering effective service.

With the close of the World War, and shortly thereafter, naval aviation was administered through the director of naval aviation in the office of the chief of Naval Operations. Our engines were handled by the Bureau of Engineering, just as are the engines of the surface ships. Our aircraft were built and designed by the Bureau of Construction and Repair, just as are surface ships. Since, however, we were on the eve of a very rapid development, it was felt necessary to consolidate aviation activities in one bureau. This resulted in the organization of the Bureau of Aeronautics, of which Rear Admiral Wm. A. Moffett, U. S. Navy, became the first chief on September 1, 1921.

U. S. NAVAL AIRCRAFT FACTORY

The Naval Aircraft Factory was established in order to assist in solving the problem of aircraft supply which faced the Navy Department upon the entrance of the United States into the World War. The Army's requirements for an enormous quantity of planes created a decided lack of interest among aircraft manufacturers in the Navy's requirements for a comparatively small quantity of machines. The Navy Department therefore concluded that it was necessary to build and put into production an aircraft factory to be owned by the Navy, in order, first, to assure a part, at least, of its aircraft supply; second, to obtain cost data for the Department's guidance in its dealings with private manufacturers; and third, to have under its own control a factory capable of producing experimental work.

In June, 1917, therefore, the Navy Department directed Lieutenant Commander Coburn of the Construction Corps to make a survey of the situation and to report upon a suitable location, size, and cost of a naval aircraft factory which would be capable of producing one thousand training seaplanes or their equivalent, including in this report the minimum time such a factory could be built and put into operation.

As a result of these instructions, Lieutenant Commander Coburn visited all private aircraft plants in the country and made a detailed study of them and of locations as the available time permitted. He finally recommended the use of vacant land in the Philadelphia Navy Yard as a site. On July 27, 1917, the Secretary of the Navy approved the project, and on August 10 ground was broken.

The output of the Naval Aircraft Factory to November 11, 1918, included 183 twin-engine patrol flying boats, with 50 sets of spares, valued at $5,435,000. Of these 183 boats, the last 33 were *F-5-L's*. A rate of production of one plane per day was reached in June, 1918.

After the Armistice, the factory's orders were canceled and experimental work authorized. The working force was reduced from 3,600 to 1,100 and the floor space used in manufacturing to 250,000 square feet. The great assembly building was turned into a storehouse for excess aircraft material and the original building first built in 1917 became the factory proper. On December 7, 1920, excess aircraft material, to the value of $40,500,000, which had been returned from overseas, was stored at the Naval Aircraft Factory.

During the year 1919, the factory was engaged in the manufacture of *NC-*, Vought-, and Loening-type planes and cars for non-rigid airships. The principal work was, however, the overhaul and reconditioning of service aircraft. The extent of this work in 1919 was the overhaul and issue to service of forty *F-5-L,* ten *HS,* twenty-four *R-6,* twenty-four *DH* and forty of miscellaneous types. Expenditures at the Naval Aircraft Factory in the fiscal year 1919-1920 were $2,000,000 not counting material drawn from store already paid for during the war.

In succeeding years, the development of new types of aircraft, catapults, and miscellaneous apparatus absorbed the capacity of the factory, together with the regular overhaul and repair work.

During the years 1921 and 1922, the large assembly building was gradually cleared of aircraft in storage and fabrication of girders and parts for the U.S.S. *Shenandoah* took place in this space. It is of interest to note that the bold theory of manufacture adopted during the war in building *H-16's* by progressive assembly of parts was followed in building the *Shenandoah*. The sub-assemblies built at the factory were trucked to Lakehurst and erected into an airship. The parts fitted perfectly and no manufacturing plant at Lakehurst was needed.

In line with the principal purpose of the Naval Aircraft Factory, namely, the experimental development of aircraft and their accessories, the Aeronautical Engine Testing Laboratory was transferred from the Navy Yard, Washington, to the Naval Aircraft Factory in Philadelphia in January, 1924. This laboratory, as installed at the Naval Aircraft Factory, includes four test stands, ten dynamometer rooms, store and tool room, overhaul and machine shops, photo and examination room, accessories and instrument laboratories, and drafting room. Thus the bureau's experimental work for both power plants and aircraft structures is now coördinated under one head.

In conclusion, it may be stated that the Naval Aircraft Factory represents one of the most important and vital functions of naval aeronautics. It is a first-class industrial establishment, capable of doing any kind of aeronautical work which may be required by the bureau. However, in accordance with the bureau's policy to encourage private aircraft manufacture, the work of the factory has been restricted to experimental work, repair and overhaul for the service, and the general storehouse for naval aviation activities.

THE TRANS-ATLANTIC FLIGHT

The *NC* flying boats which were used on the trans-Atlantic flight marked the culmination of the war development of aircraft in the Navy. In August, 1917, Admiral Taylor, Chief Constructor, initiated the project of building the largest flying boats in the world, to be of novel construction, and to attempt to cross the Atlantic. This project was conceived with a view to getting anti-submarine planes into the war zone independent of shipping. The plan was to produce these great flying boats in quantity and to fly them across the Atlantic to the center of submarine activity. The Armistice came before this plan could be carried out but the trans-Atlantic flight which was undertaken in May, 1919, was strictly in line with the original purpose of the design and really in the nature of a service trial. These flying boats were designated "NC," the "N" for Navy and the "C" for Curtiss, because they were the joint production of the Navy and the Curtiss Engineering Corporation. The designers of the *NC* were Mr. G. H. Curtiss and Mr. W. L. Gilmore of the Curtiss Company and Commanders Westervelt, Richardson, and Hunsaker of the Navy.

The hull of the *NC* was 45 feet long by 10 feet beam. The total wing area was 2,380 feet. It was capable of an endurance of 1,400 miles, carrying a crew of five men with all necessary food, water, and equipment. The radio was of sufficient power to communicate with ships 500 miles away. The radio phone could be used to talk to the other planes in formation, or to ships within 25 miles. The *NC* weighed, fully loaded, 28,000 pounds.

The tail surfaces of the *NC* were made up as a biplane which resembled in general appearance and size the usual airplane. The *NC* tail was in fact twice as large as the ordinary complete single-seater fighting airplane. The tail was over 500 square feet in area and the structure was supported by three hollow spruce booms braced by steel cable in such a way as to remain clear of all breaking seas and to permit a machine gun to be fired straight aft from the stern compartment without interference. This method of support was a radical change from former American and foreign practice but resulted in several advantages besides an important saving in weight.

The four Liberty engines which drove the boat were mounted between the wings. At 400 horse-power per engine, the maximum power was 1,600 horse-power, or with the full load of 28,000 pounds, 17.5 pounds carried per horse-power. One engine was mounted with a tractor propeller on each side of the center line and on the center line the two remaining engines were mounted in tandem, or one behind the other. The front engine had a tractor propeller and the rear engine a pusher propeller. This arrangement was novel and had the advantage of concentrating weights near the center of the boat so that it could be maneuvered more easily in the air.

The first of the *NC's* was completed and flown on October 4, 1918, approximately one year after the commencement of the design.

The three flying boats, *NC-1, NC-3,* and *NC-4* were placed in regular commission on May 2, 1919, and Commander J. H. Towers, U. S. Navy, assumed command of *NC* Seaplane Division One, comprising these three boats. This was the first time in the history of the Navy that any aircraft had been placed in regular commission. In addition, Commander Towers was detailed to command the *NC-3,* which, therefore, became the flagship of the division; Lieutenant Commander P. N. L. Bellinger was detailed to command the *NC-1;* and Lieutenant Commander A. C. Read, to command the *NC-4.*

The route from Newfoundland to Portugal via the Azores was chosen because its distances were the shortest and its areas of uncertain weather conditions the least. A patrol of destroyers was established along this route so as to reduce the danger to personnel to a minimum. At all ports of call, mother ships were stationed in order to provide fuel, spare parts, repair facilities, etc., for the planes.

All three planes were flown to Trespassy Bay, N.S., where the *NC-4* received a new engine, having experienced trouble on the way, and finding it necessary to taxi part of the distance.

The start from Trespassy for Horta, a port in the Azores, was made on the afternoon of May 16.

Formation was assumed and was fairly well preserved during the afternoon and early evening. Later when it became dark and overcast, however, and the running lights of the *NC-3* stopped functioning due to grounding of the circuit by salt spray, the three planes were soon lost to each other and each continued the flight independently. A little before dawn the *NC-4* began flying much faster than either the *NC-1* or *NC-3,* because its pilots did not feel entirely stable at the higher angle of incidence given by lower speed. About eight o'clock in the morning the three planes encountered intermittent rainfalls, and a very thick fog. As the Azores were approached the fog became thicker and thicker and

interfered seriously in determining the course which was being flown, as it was impossible to obtain a reliable sextant altitude of the sun. Various altitudes were tried to avoid the fog, but it merged with the clouds which, most of the time, extended very high and made flying at any altitude over 1,000 feet very difficult for the pilots.

Shortly before noon the *NC-1* landed for the purpose of determining its position by taking radio compass bearings on destroyers but the water conditions were worse than had been expected and entirely too rough to take off into the air again. About a 22-mile wind was blowing, with a cross sea and a heavy swell. For four hours attempts were made to call to destroyers for aid by means of the radio but with no success. In the meantime the sea had carried away the elevators, and a portion of the wings. Finally late in the afternoon the crew of the *NC-1* were picked up by a passing steamer, the Greek ship *Ionia,* and taken to Horta while the plane itself was subsequently sunk to remove a menace to shipping.

At 1:30 P.M. on May 17, the *NC-3* also landed in order to obtain radio compass bearings and was unable to take off again due to the rough sea and to damages received in landing. The plane's position was obtained, however, by means of radio compass bearing as being 34.5 miles southwest of Horta. Due to injury of the radio apparatus evidently received while landing, the *NC-3* now found itself able to receive messages but unable to send any, except on a short-range battery set. Those messages, however, were not intercepted by the station ships. A heavy storm arose that afternoon, and for two and a half days the *NC-3* fought the storm, and endeavored to utilize her very limited sailing qualities toward getting to the island of San Miguel. This was finally accomplished, and on the evening of May 19, the *NC-3* sailed into the port of Ponta Delgada.

The *NC-4* reached Horta safely on the afternoon of May 17, completing the distance of 1,200 nautical miles from Trespassy to Horta in 15 hours and 18 minutes. The *NC-4* was thus the only plane left to continue the flight. The personnel of the other two planes were taken aboard the *Bainbridge* to Lisbon, and thence to Plymouth by the *Rochester.*

The *NC-4* was held at Horta by fog and gale until May 20. On the afternoon of this day, the flight was continued to Ponta Delgada, where six days more were consumed awaiting favorable sea and weather conditions. Finally, early in the morning of May 27, the *NC-4* departed from Ponta Delgada, and arrived at Lisbon late in the afternoon of the same day, thus being the first aircraft to cross the Atlantic Ocean by air.

SUMMARY

Admiral Moffett has made a very effective summary of the aeronautical successes of the Navy:

> As a matter of actual fact, the Navy has been itself responsible for more real effective development in the field of aeronautics in this country than has any other one agency. From the earliest days of mechanical flight, officers of our own Navy have recognized its potential value to naval warfare, and have been actively engaged in flying operations and the study of aeronautics—experimenting in adapting aeronautics to the needs of the Navy.

It was the Navy that first in this country successfully employed the radio telegraph as a means of communication with aircraft; the Navy that first employed the radio compass in aircraft; the Navy that first used observations of heavenly bodies for fixing aircraft positions in flight; the Navy that operated the first amphibious airplane, the first all metal airplane of American manufacture, the first practicable dirigible airship. It was the Navy that conceived and perfected airplane launching devices from ships. It was the Navy that first crossed the Atlantic by air. It was a naval officer who was called upon by the Massachusetts Institute of Technology to operate the first American wind tunnel, and whose pioneer researches in aerodynamics, while detailed there, have since stood as the fundamental basis of all aircraft design in this country, and have been quoted as authority in all foreign countries. The first United States combatant force to be landed in Europe in 1917-1918 was a small naval aviation detachment. The first American-built aircraft to be placed in flying service in the War zone were Navy-built flying boats.

In excellence of equipment, in material development and construction, in all fields of aeronautic activities, the Navy has been and is in the forefront.

I mention these things here as indicating that whatever advance has been made in naval effectiveness through the use of aircraft is due to the Navy's own spontaneous efforts, and that the aviation activities that are becoming so common are *of* the Navy, not merely *with* it, an extension of its activities and power, not a curtailment, nor a replacement of existing equipment.

Courtesy Edward L. Shuford, P.2C, U. S. Navy.

U.S.S. "Langley" Operating at Sea
From a charcoal painting by E. L. Shuford, P.2C, U. S. Navy

CHAPTER II

MISSION OF NAVAL AVIATION

The aviation activities of the government are concentrated under three federal departments—the War, the Navy, and Commerce. The "Army Air Service" and "Naval Aviation" are essentially and actually military. Naval and Army aviation necessarily parallel one another in many fields of development. To avoid duplication of effort and to provide for systematic coöperation between the services the "Aeronautical Board" has been established. The order establishing this board *(General Order 132)* also announces the national aircraft policy agreed upon, and assigns to each service of military aviation its own particular strategic field.

Strategy and tactics of the air at sea and on the land are basicly the same, but the application is different in each case. The following pages are devoted to naval aviation as employed in hostilities on the sea, considering aviation in its present state, and as an actively engaged arm of the fleet.

It was early recognized that aviation in the fleet had two major rôles. The first we may call air service, and by that we mean that portion of aviation which assists the ships in their own activities. Under this heading, we include scouting and the observation of gunfire; that is, "the eyes of the fleet." The second major rôle is that of air offensive, and under this heading we include that portion of naval aviation which carries out the offensive rôle. Under this heading, we include bombing, light bombing, machine-gun attacks, torpedo dropping, and attacks on enemy aircraft.

Naval air effort being one of the important elements that make up the whole naval force, it must conform to the same fundamental requirements that control in the development of all naval forces: (1) that it is justified only to the extent that it exerts an important influence on control of sea areas; and (2), that it must be capable of operating effectively in any part of the oceans of the world.

In the last war when the Navy carried out the great work of maintaining our sea communications and of carrying the Army across the water, district naval forces played a most important part in winning the war. Naval aircraft patrolled over 2,500,000 miles from the various air stations along the coasts of the United States, England, France, Ireland, Italy, and Canada. Four hundred naval airplanes were engaged in this work in the coastal waters of Europe alone, and made thirty-seven attacks upon enemy submarines. In addition to these naval aircraft, operating with them as a part of the organization engaged in keeping open the coastal sea lanes were other naval vessels of various types including submarines.

Experience having indicated that airplanes in normal operations are, at least in the present state of the art, incapable of operating unsupported on the vast areas of the sea, naval force cannot avail itself of the advantages inherent in air operations unless it provides in the fleet itself means for carrying, maintaining, and efficiently operating aircraft in whatever area it becomes necessary to exert

sea power, and unless through constant training there are developed methods for harmonious coöperation between air, surface, and subsurface activities.

Work of this nature is seldom spectacular; it involves few, if any, brilliant or "epoch making" exploits on the part of individuals. It is rather a process of meticulous attention to multifarious details, which to the casual observer appear commonplace.

Officers afloat are most concerned with the aircraft operating with the fleet. Aircraft for these operations will be supplied from three principal sources—carriers, tenders, combatant ships. Rigid airships are expected to accompany the fleet as independent units. Capital ships and cruisers have been supplied with planes to be launched by catapult and it is contemplated that similar installations will be provided on some train ships and destroyers.

The primary function of the fleet is to gain and exercise control of the sea. The accomplishment of this task will probably require it to discover, engage, and destroy the enemy fleet. Discovering the enemy is a problem in scouting.

The rigid airship with its relatively high speed and long radius is a good long-range scout. Also, by the use of one or more airplanes, the area covered by a surface scout is greatly increased.

After contact is made the commander in chief will strive to engage the enemy under conditions favorable to himself. To do this he must keep in touch with the enemy's movements. The enemy by use of smoke screens may be expected partially to conceal his movements. Probably the most effective means of reducing the value of his screens is through the air scout.

Another important employment of the airplane is observing the fire of the fleet. At the present time great success has been had with control of fire of surface craft by aircraft. The advantage gained by successful fire control in this manner is evident. Great guns on the latest battleships are made to fire at a maximum range of nearly 40,000 yards. From the masts of the firing ship, on a clear day, only the topmasts of the enemy are visible at this range.

These two functions (scouting and spotting) of the airplane fall under the term of "air service." Important as they are to the fleet, it is expected that the greatest use of the airplane in the future naval battle will be rendered by it as an actively engaged combatant. At present the demolition bomb and the two calibers of machine guns may be considered the primary weapons of offensive aviation. The most likely targets for light bombs of various sorts are the enemy aircraft carriers and ships of the enemy lighter than capital ships. The fragmentation bomb is designed for use against personnel and for this reason does not have the possibilities presented for its use at sea that exist on land. It must be remembered that the United States is one of the signatory powers to a convention which prohibits the use of poisonous or asphyxiating gases or liquids in war between themselves. On account, however, of the possibilities of a war with a power which has not signed the convention, the use of this weapon must be taken into account. Research and construction of various gas bombs for use from airplanes has been allocated to the Army.

The launching of torpedoes from airplanes has proven practical and effective since 1919. We have equipped and successfully operated many torpedo-plane squadrons. Since torpedoes must necessarily be dropped from a low altitude,

the tactics used in so doing differ entirely from the tactics of bombing. The enemy must therefore develop a special defense against them, thus further complicating his problem of defense against all aircraft. The torpedo-plane attack might never take place during battle but its *potential threat* is an important factor.

Successful bombing, torpedoing, and observation of gunfire by aircraft will require at least temporary control of the air. As the opposing fleets of a future war come into contact we may expect to see a struggle in the air for control. The fighter here finds its justification. The combatant whose air forces maintain the air will have gained a tremendous advantage.

The primary mission, then, of naval aviation in war is to obtain local control of the air immediately preceding a naval engagement, and to maintain it during the engagement, in order that friendly forces may enjoy the tremendous advantage gained by unmolested aircraft activity while denying it to the enemy.

When the test comes the results depend greatly upon the effort that has been spent upon development.

The air policy of the government is set forth in *General Order 132,* which follows:

GENERAL ORDER } NAVY DEPARTMENT,
No. 132 } WASHINGTON, D.C., *7 July, 1924.*

AIRCRAFT POLICY

I. Policy of the Army and Navy relating to aircraft.—The following policy of the Army and Navy relating to aircraft has been approved by the joint Army and Navy board, the Secretary of War, and the Secretary of the Navy, and is published for the information and guidance of all concerned:

1. Aircraft to be used in the operations of war will be designated—
   a. Army aircraft.
   b. Navy aircraft.
   c. Marine aircraft.

Army aircraft are those provided by the War Department and manned by Army personnel.

Navy aircraft are those provided by the Navy Department and manned by Navy personnel.

Marine aircraft are those provided by the Navy Department and manned by Marine Corps personnel.

The Marine air service is a branch of naval aviation.

2. The functions of the Army, Navy, and Marine aircraft are as follows:
   a. **Army aircraft.**—Operations from bases on shore—
      (1) As an arm of the mobile army;
      (2) Against enemy aircraft in defense of all shore establishments;
      (3) Alone or in coöperation with other arms of the Army or with the Navy, against enemy vessels engaged in attacks on the coast, such as—
         (a) Bombardment of the coast,
         (b) Operations preparatory to or of landing troops,
         (c) Operations such as mine laying or attacks on shipping in the vicinity of defended ports.
   b. **Navy aircraft.**—Operations from mobile floating bases or from naval air stations on shore in coöperation with the fleet:
      (1) As an arm of the fleet,
      (2) For overseas scouting,

(3) Against enemy establishments on shore when such operations are conducted in coöperation with other types of naval forces, or alone when their mission is primarily naval,

(4) To protect coastal sea communications by—

(a) Reconnaissance and patrol of coastal sea areas;

(b) Convoy operations;

(c) Attacks on enemy submarines, aircraft, or surface vessels engaged in trade prevention, or in passage through the sea area.

(5) In coöperation with the Army against enemy vessels engaged in attacks on the coast.

c. **Marine aircraft.**—The functions normally assigned to Army aircraft will be performed by the Marine aircraft when the operations are in connection with an advance base in which operations of the Army are not represented. When Army and Marine aircraft are coöperating on shore, the control of their operations will be governed by the 120th Article of War.

3. The functions of aircraft assigned in paragraph *2a* (3), under **Army aircraft,** and in paragraph *2b* (5), **Navy aircraft,** are a duplication of functions. In such operations coöperation is vital to success. Such coöperation will be governed by the following provisions:

a. The Naval District Forces, vessels, and aircraft will never be strong enough to prevent an attack on the coast by major units of the enemy fleet. When therefore, an enemy force of a strength greatly superior to that of the naval force available for use against it approaches the coast, the commander of the naval force will inform the commander of the Army Department of the situation, will assume that the Army has a paramount interest in the operation, and will coördinate the operations of the naval forces with those of the military forces.

b. If, however, the conditions are such that the enemy is, or can be, engaged by a naval force approximating in strength to that of the enemy, the commander of the Army Department will be so informed, and he will assume the Navy has a paramount interest in the operation and will coördinate the operations of the military forces with those of the naval forces.

4. The functions of the aircraft assigned in the foregoing paragraphs will govern in the production of aviation equipment, training of aviation personnel, and establishment of air stations for the War and Navy Departments. Such assignment will not prevent the employment of Army and Marine aircraft in naval functions upon the request of the senior naval officer present, or vice versa, the employment of naval aircraft in Army functions upon request of the senior Army or Marine Corps officer present on shore; nor will it prevent the employment of Army, Navy, or Marine aircraft when no other air service is coöperating in the operation, in any manner which shall be most effective in accomplishing the mission of the force.

5. All questions regarding the policy of the War and Navy Department with regard to the tactical and strategical functions of aircraft, and to the location of air stations, will be addressed to the Joint Board for consideration and recommendation to the Secretary of War and the Secretary of the Navy.

II. The Aeronautical Board.—In order to prevent duplication of effort and to secure a more complete measure of coöperation and coördination in the development and employment of the Army Air Service and Naval Aviation, the Secretary of War and the Secretary of the Navy have agreed upon the reorganization of The Aeronautical Board with functions, membership, and procedure as follows:

1. The Aeronautical Board will investigate, study, and report upon all questions affecting jointly the development and employment of the Army Air Service and Naval Aviation, referred to it by the Secretary of War, by the Secretary of the Navy, or by The Joint Board. It will also be charged with the duty of originating consideration of such subjects when, in its judgment, it is necessary, and of recommending whatever

it considers essential to establish sufficiency and efficiency of coöperation and coördination of effort between the Army Air Service and Naval Aviation.

2. In the execution of the foregoing the following will govern:

a. All recommendations of The Aeronautical Board affecting joint policies or strategical employment of aircraft or for the location of air stations, will be addressed to The Joint Board for consideration and recommendation to the Secretary of War and the Secretary of the Navy.

b. The Aeronautical Board will formulate and submit to The Joint Board for approval, suitable joint Army and Navy aircraft problems to be carried out each year.

c. The Chief of Air Service of the Army and the Chief of the Bureau of Aeronautics of the Navy will submit to The Aeronautical Board all questions which concern jointly the Army Air Service and Naval Aviation.

d. The development of new types of aircraft, aircraft motors and aircraft accessories, or of weapons to be used from aircraft will, so far as practicable, be assigned to the Army or Navy and shall be carried on only by the service to which assigned. This restriction will not prevent the employment by either the Army or Navy of any types of aircraft or weapons which, after development, are considered to be necessary for the accomplishment of its functions. Questions relating to the development of new types of aircraft, aircraft motors, and accessories or weapons to be used from aircraft will be referred to The Aeronautical Board for recommendation as to whether the Army or Navy shall be charged with the development.

e. Whenever possible, training, repair, and other aviation facilities of either the Army or Navy will be made available for or be used by the other service.

3. The Aeronautical Board is specifically charged with the following:

a. Plans to prevent competition in the procurement of material. Before arranging to purchase aircraft, each service will ascertain whether aircraft of the type desired can be obtained from the other service. Joint plans for procurement of material in time of war will be submitted to the Army and Navy Munitions Board.

b. Consideration and recommendation of all projects for experimental stations on shore, for coastal air stations, and for stations to be used jointly by the Army and Navy, or for extensive additions thereto.

c. Consideration of and recommendation in regard to all estimates of appropriations for the aeronautical programs of the Army and Navy before such estimates are submitted to Congress.

d. Coördination of the activities of the Army Air Service and Naval Aviation in the purchase of material abroad and coördination of their activities with the aeronautical activities of other branches of the Government and with civilian aeronautical organizations.

e. Recommendations as to action to be taken on invitations of foreign governments to participate in aviation activities abroad and on the invitations of civilian organizations to participate in such activities in the United States.

f. Cognizance of the issuing of licenses to civilians to operate aircraft in time of war.

4. The membership of The Aeronautical Board will consist of:

a. **For the Army:**

The Chief of Air Service, the Chief of Training and War Plans Division, Office of Chief of Air Service; one member of the War Division, General Staff, War Department, to be designated by the Chief of Staff of the Army. The last-named member, while holding such office, will not be eligible for duty with The Joint Board or Joint Planning Committee.

b. For the Navy:

The Chief of the Bureau of Aeronautics; the Chief of Planning Division, Bureau of Aeronautics; one member of the War Plans Division, Office of Chief of Naval Operations, to be designated by the Chief of Naval Operations. The last-named member, while holding such office, will not be eligible for duty with The Joint Board or Joint Planning Committee.

5. The secretary of the board will be selected by the Secretary of War and the Secretary of the Navy from the permanent personnel of either department and detailed to this duty.

6. The Aeronautical Board will hold regular monthly sessions and such extraordinary meetings as may be deemed advisable. The board will prescribe its procedure. The senior member of the board present will preside at its meeting. The reports and correspondence of the board will be authenticated by the senior officer of the Army and senior officer of the Navy present at the meeting at which the action was taken.

CURTIS D. WILBUR
Secretary of the Navy

Courtesy Glenn L. Martin Company.

THE THREE PURPOSE PLANE

Navy T4M-1 (Martin "74") all metal plane, for bombing, torpedo, and scouting.
Designed for use on the *Lexington* and *Saratoga.*

CHAPTER III

ELEMENTARY AERODYNAMICS

Aerodynamics treats of the forces produced by air in motion. Present aerodynamic data are based largely upon experimental investigation, a large portion of which has been secured from scale models or full sized sections placed in a wind tunnel.

Successful flight involves three essentials: sustentation, stability, and control.

Sustentation (lift) may be achieved in four ways. In balloons and airships it is secured by an application of the principle of Archimedes. That is, a body immersed in a fluid is buoyed up by a force equal to the weight of the medium displaced.

The ornithopter sustains itself by forcing the air downward and backward under the flapping surfaces. It is an imitation of bird flight. On account of mechanical difficulties none of these machines have ever been successful.

The helicopter obtains sustentation by the employment of propellers revolving on a vertical shaft. The lift is obtained by the reaction of the propeller alone. Several of these machines have been built which will sustain themselves but none of practical value have ever been built. Lack of sufficiently powerful engines is one reason for failure, and the problem of safe descent in case of engine failure is yet unsolved. It is reasonable to believe, however, that in future years successful helicopters will be constructed.

The fourth method of sustentation is that employed by the airplane. The airplane is enabled to rise from the ground by virtue of the fact that owing to its motion, there is a vertical component to the total air force (that is, a lift), which is greater than the weight of the airplane. This lift is secured from the wings (airfoils) which deflect downward the air stream and thus derive a reaction equal and opposite to the imparted momentum. The lift is secured at the expense of a certain amount of drag. It is this wing drag together with the drag of other parts of the airplane which must be overcome by the thrust of the propeller in order that flight may be maintained.

Lift is obtained partly by the under surface of the wing driving the air downwards, but to a far greater extent by the negative pressure on the upper surface of the wing, the latter giving about 70 per cent of the total lift.

The amount of the lift is greatly dependent upon the shape of the airfoil. Wind tunnel experiments have determined that the cambered one not only gives greater lift but also has less drag.

The control of an airplane is complicated because it must be complete, that is, three dimensional. In a steamship, for example, there is strict freedom of motion on a horizontal plane only, so that a directional control is sufficient. An airplane may pitch, roll, or yaw, so that three controls are required. Pitch, or motion about the lateral axis, is controlled by the elevators; roll, motion about the fore-and-aft axis, by the ailerons; and yaw, by the rudder.

The control of an airplane is usually made to correspond to the pilot's instinctive motions. Pitch is controlled by a "stick" or control yoke, which is pulled back to nose-up or pushed forward to nose-down. In roll, the stick is pushed over towards the side which is to go down—or with the wheel control, the wheel is rotated towards the side to go down. Yaw is controlled by a foot rudder bar or pedals pushed by the foot on the inside of the turn.

Stability is very closely associated with control, and may be defined as the property which causes an airplane to return and remain at a fixed flight attitude after being deflected from this attitude by some external cause, such as a gust.

There are two distinct, but not easily separated, types of stability—static and dynamic. Static stability sets up a restoring moment after the airplane has been deflected from its normal flight path. Dynamic stability damps out the oscillations which result from this restoring moment.

A stable airplane is not readily thrown off its course and once off tends to return. An unstable airplane, when left to itself, may either dive, stall, side slip, or spin, from any slight disturbance.

Considered from the standpoint of their importance in contributing to flight the parts of an airplane are:

(1) Wings and stabilizing surfaces.
(2) Controls and control surfaces.
(3) Power plant.
(4) Landing gear.
(5) Fuselage.

Minor parts, such as radiators, struts, wires, fittings, etc., have no direct function in flight, although they are necessary in practice.

The wings may be disposed in many arrangements, such as monoplane, biplane, triplane, multiplane, or tandem. Theoretically the monoplane arrangement is the best, but in any given design there may be practical considerations which prevent its use. For example, a large boat-type seaplane will require so much wing area that in the monoplane form the span or spread is too large. Since monoplanes of large span are very heavy in construction and difficult to handle at all times, a biplane or triplane is preferable.

The performance of a plane depends, not only upon wing arrangement but upon the characteristics of the airfoils used in the wings, the weights and their disposition, and the efficiency of the power plant. The performance of a plane is the result of the effort of the designer to combine the conflicting aerodynamic requirements of maximum speed, maximum climb, and maximum facility of control. The result, of course, depends largely upon the service the plane will be required to perform. In practice the performance of a plane is tested and judged by the following tests:

(1) Maximum and minimum speed at various altitudes.
(2) Landing speed.
(3) Rate of climb at various altitudes.
(4) Absolute ceiling (maximum altitude obtainable).
(5) Service ceiling (altitude at which rate of climb becomes 100 feet per minute).

(6) Climb in ten minutes.
(7) Endurance at high speed, and at cruising speed.
(8) Range at high speed, and at cruising speed.

In order that performance tests may be of value for comparison, it is necessary to specify the weight and power at which they are obtained. For the endurance and range test the weight of fuel loads at the start is specified.

It is apparent that a single type of plane cannot combine the speed and maneuvering ability required for combat with the load-carrying ability and large fuel capacity which bombers and long distance reconnaissance planes must have. An additional limitation is placed upon planes working with the fleet by the fact that they must operate, not from a smooth and generous landing field, but from the restricted deck of a ship. The development of the catapult has greatly simplified the problem of departure, but for the purpose of maintaining morale, and conserving equipment, it is highly essential that planes be able to return without being damaged by landing.

To gain an idea of the effect of changing the various factors which govern the performance of an airplane consider the combat type. The most important factors of a fighting plane are speed and maneuvering ability. Speed must be a maximum both horizontally and vertically, for climbing ability is of equal importance with horizontal speed. An additional important consideration is a high maximum attainable altitude or "high ceiling." A high ceiling is quite compatible with a high rate of climb since a fast climber generally but not necessarily has a correspondingly higher maximum altitude.

Take each of these requirements in turn. High speed and maneuvering ability call for small wing areas, short spans, and concentration of weights at the center of gravity. The areas are so adjusted that they have minimum resistance at highest speeds. Power plant, fuel supply, and pilot are crowded into the smallest possible space. One of the factors which contributed so largely to the early popularity of the radial and rotary motors was their extremely short fore-and-aft dimensions, which favored the utmost concentration of weight. Further, since resistance increases approximately as the square of the velocity, the most efficient wing sections and the most careful refinements of streamline must be employed.

If we attempt to improve the performance of a combat plane we find certain factors difficult of reconciliation. Suppose we increase the power plant. This means a larger engine with a uniform increase in over-all dimensions, greater weight, and increased fuel consumption, which together may reduce to a negative quantity the advantages expected as a result of adding power.

If we seek to diminish wing resistance and increase maneuverability by decreasing the wing area, we find that the most favorable wing areas at high speed are too small for landing speeds. With a fixed wing area the minimum landing speed is only a little less than one-half the maximum speed. With our present knowledge of design, a maximum sustained flying speed of about 200 miles per hour has a landing speed of 50 to 70 miles per hour. Such a landing speed requires the very highest of flying ability even when landing on excellent landing fields. An aircraft carrier's deck rolling about at sea offers immensely greater difficulties.

If we attempt to improve a combat plane's performance by decreasing the weight of the plane's structure, we find that this process, too, must be carried on with great care. Increased speed of flight necessitates an increasingly strong structure not only for straight flight and maneuvering but also to withstand the extreme shocks of landing, which become more and more severe as the landing speed increases. Further, from evidence gathered at speed trials and races, it became manifest that our frail structures of wood and fabric would prove inadequate to stand the stresses which speeds above 200 miles an hour impose. Construction, therefore, tended to light steel and aluminum alloy fuselages and wings, with the result that all modern naval planes are all-metal, or with all-metal fuselage and wing skeleton and fabric covering. The limit in weight cutting in high speed aircraft, *without radical change of design,* is very clearly defined.

It may be seen from the above notes that improvement in combat plane performance with reference to speed and maneuverability is controlled by the necessity of a careful balance of all the factors concerned. The most promising opportunities for improvement at this time lie, apparently, in a reduction of the power-plant weight, without the reduction of power, and in the development of an adjustable wing permitting high speed flight and low speed landings.

Climbing ability and ceiling are dependent on excess horse-power. Great climbing ability means a large power reserve, hence the weight carried per horse-power is reduced to 6 to 8 pounds on scouts and fighting planes in contrast to the 16 to 25 pounds per horse-power carried on larger and slower planes. This reduction in weight per horse-power is accomplished in part by the employment of a high performance engine, small fuel capacity, one instead of two pilots, and to a small extent, by a sacrifice of strength in favor of light weight. This sacrifice of strength of course reduces the safety factor.

The question of obtaining a high ceiling for a plane seems well advanced towards a solution, particularly as regards the power plant. Present developments indicate that it is possible to secure excellent engine performance by means of supercharging, as high as 45,000 feet. The perfection of a propeller adjustable for altitude would assist in the solution. In considering the desirability of a high ceiling, it must be borne in mind that the military advantage gained by dragging a plane up to excessive heights may be lessened because of the diminished maneuverability of the plane at that altitude and the handicap which breathing apparatus, low temperature, and low atmospheric pressure place upon the pilot.

The necessity, however, for a relatively high ceiling for the fighters is well brought out by the following story. Captain Rickenbacker, U. S. Army, had made several contacts with a German *Rumpler (No. 16),* but had been unable for various reasons to bring it to a decisive action. He tells the story of his next encounter:

> The very next day I went in my own machine with just the one resolve burning in my brain. I saw nothing else in the sky and searched for nothing else. In fact I had scarcely gained my very topmost altitude and set forth in the direction of what I knew was the favorite path of this daily visitor before I saw him coming to meet me. It was almost as if we had met by appointment.
>
> As I have said, I reached my very highest altitude before going forth to this tryst. Some *Nieuports* have a higher ceiling than others. It depends upon the quality and natural fitness

of the motor. My bus reached 18,000 feet that morning. It had just been fitted with two Vickers' guns instead of the one it formerly carried. This additional weight of 30 or 40 pounds hampered the climb somewhat and lowered my ceiling by at least 500 feet.

Try as I would I could get her no higher. As we approached each other, *No. 16* and I, the *Rumpler* was at 20,000 feet and was still climbing. My Boche friends knew perfectly well they could climb higher than any *Nieuport*. It might make their photographs a little indistinct but even those were better than our own taken from 12,000 feet. They came steadily on and I turned as they passed me and continued a parallel course some 2,000 feet below them.

The railroad stations at Nancy and Toul were their objectives this morning. Without deigning to pay any attention to me they proceeded over their course and deliberately snapped their pictures. Occasionally the observer amused himself with a little target practice at me. At such times I realized that he had nothing else to do, so concluded obviously that he did not desire photographs of those parts of his voyage.

I too fired long bursts upwards. I had no idea of hitting them at that long range. It merely served to keep them informed that I was still in their company. They knew they had me at their mercy as far as giving me a chance at a combat.

So we continued along all over the northeast of France. I suppose most of the films they developed that afternoon showed the wings of my *Nieuport* below them.

My one chance was to keep below them and follow them until they came down. As there is no record of any German machine not coming down finally I determined to follow the Boches back to Berlin if necessary, in order to get a shot at them when they passed my level. Thus we crossed the lines and proceeded steadily northwards. I could outfly the *Rumpler* and out dive him, but his superior engine power and greater wing spread gave him a much higher ceiling.

After seeing mile after mile slip away beneath my wings and still no evidence of change of heart in my antagonists I began to speculate upon the quantity of gasoline the *Rumpler* carried. I knew too well the limits of the *Nieuport's* fuel supply. And the disadvantage again lay with me. For if we both became exhausted at the same time the *Rumpler* would be in his own territory while I would be many hostile miles from my own.

With savage realization that I was again defeated I turned around and took my way homewards. I could imagine my two Boche adversaries laughing at me as I gave up the chase. They began to glide downwards as soon as I turned my back. I sheered back at them just to have the satisfaction of showing them I was still their master. Very obediently they altered their tactics and again climbed for their superior ceiling.

When I reached camp I scoured the hangars for information of the highest climbing machine on the airdrome. My comrades followed me about, supplying me with much gratuitous information and advice. They advised me to leave off both guns next day which might permit me to reach 20,000 feet. Or if I took no fuel along I might go to 30,000 feet. Uncomplimentary references to the weight of my shoes and the heaviness of my grouch aided me considerably.

Power, and Its Relation to Dimensions of Airplanes

There are, broadly speaking, two methods of procedure whereby the gross lift of the airplane may be increased. We may either increase the size of the wings, keeping the speed the same, or we may increase the speed, keeping the size of the wings the same.

Considerations of safety in taking off and landing place very definite limits on increases in minimum flying speed. Bearing in mind these limitations, there is no merit, practically speaking, in increasing the speed, for the following reasons.

The lift of an airplane wing varies approximately as the square of the speed. But the resistance (and hence the thrust required) also varies as the square of the speed. And since power is the product of thrust times speed, the power required varies as the *cube* of the speed. Thus, if we wish to double the speed of

an airplane, we shall get four times the lift, but we require eight times the power and eight times the fuel. In other words, with increase in speed, the weight of the engine and fuel increases much more rapidly than does the lift of the wings. These figures do not give a numerically accurate measure of the results actually obtained when reduced to practice, since other important considerations exert a strong influence. But they do indicate tendencies and explain the actual fact that extremely high speed airplanes are very poor weight carriers and have a comparatively short cruising radius.

Increase in size has some little merit, but not nearly to the extent as might be supposed. The lift of a wing is a function of its area, other things being equal, i.e., speed, wing form, etc. Two square feet of wing surface has double the lift of one square foot. So that, if we double the wing area, keeping the speed the same, we double the gross weight that can be carried. But when we double the wing area, we also double the air resistance, and hence double the power required, double the rate at which fuel must be consumed, and hence double the weight of fuel which must be carried to fly a given distance. Theoretically speaking, therefore, we should expect to carry exactly the same load for exactly the same distance with two small airplanes that we can carry with one big one of equivalent wing area. This is not strictly true, when reduced to actual practice, because power-plant and installation weights do not necessarily increase in direct proportion to increase in power, nor is it, for example, necessary to provide for a large airplane an operating crew twice as large as is required for a small airplane of half the size. As a generalization, however, it is a practical fact that increase in size has in itself very little merit so far as cruising radius is concerned. In other words, we can fly very nearly as far and carry very nearly as much useful load with two small airplanes as we can carry with one big one of equivalent size. And it is extremely doubtful that men now living will see the day when mammoth armored battleships of the air will descend upon us from across the sea, or when the giant submersible equipped with folding wings will emerge from the water and swarm in over our sea coast, hurling death and destruction on all sides. A description of such a craft appeared in the British press—and was copied widely in the American press—a description which was alleged to be entirely authentic.

AIRSHIPS

The airship, being purely a displacement vessel which derives its lift solely from the static buoyancy of the air displaced, is in quite different case from the airplane. Here the power available has no relation whatever to the gross weight which can be carried. It merely determines the speed at which the airship may be driven through the air. There are no minimum speed requirements; the ship can, theoretically at least, remain afloat in the air indefinitely without the expenditure of an ounce of fuel. Being a displacement vessel, the gross weight that can be supported is determined by the volume of the bag, which varies, of course, as the cube of the dimensions. The resistance at any given speed is purely a function of the area of the exposed surfaces and hence varies only as the square of the dimensions, and since the power required is determined entirely by the resistance, it follows that for a given speed the power required varies with the square of the dimensions. The gross lift, be it remembered, varies as the cube of the dimensions.

In other words, if we double the dimensions of an airship we shall have increased the gross lift eight times, and the power required to drive it only four times, which is equivalent to saying that the possible carrying capacity or cruising radius of an airship increases very rapidly with increase in the dimensions of the ship, and within the limits of practicable construction any radius desired may be realized. It is quite possible at present to build airships which can cruise with the fleet continuously under their own power, and which would require refueling or reprovisioning no more often than do the surface ships.

The performance characteristics of an airship are in general as follows:

(a) Maximum speed at various altitudes.
(b) Maximum altitude attainable with definite weight relations.
(c) Endurance at full power and half power.
(d) Static ceiling.
(e) Dynamic lift under specified conditions.

Airship Operation

Airships, like submarines, float wholly immersed, and there is no change of buoyancy as they ascend or descend, provided ascent is not carried beyond the point at which the gas space becomes completely filled. Below this height the variation in the density of air is balanced by the contraction or expansion of gas, so that the weight of air displaced and hence the buoyancy of the ship remains constant.

In a nonrigid airship, the pilot must maintain the gas pressure between narrow upper and lower limits by forcing air from the propeller slip stream through scoops into the ballonet, or by opening the air relief valves on the ballonet, or by rising or descending. (The ballonet is a flexible bag inside the envelope used to fill the excess space and maintain pressure inside the envelope when, for any reason, the gas contracts.) If the pressure rises above about 3″ of water, the envelope will be unduly strained, and if the pressure falls below about 1″ of water, the envelope may buckle and become unmanageable, or the bow may cave in. A blower is sometimes provided to maintain the pressure when the main engines are at rest. In a rigid airship, the gas is contained in cells, the lower parts of which are always flabby, except when the cells are completely full of gas. Automatic pressure relief valves are provided for the escape of gas when the airship rises so high that the cells are fully inflated with a pressure of about 0.5″ of water at the bottom. The rigid airship pilot is thus almost entirely relieved of anxiety about gas pressure, which is the constant pre-occupation of the nonrigid airship pilot.

Inequalities between the buoyancy and the weight of the ship occur due to the expenditure of fuel, or from a difference between the temperature of the gas and the surrounding atmosphere. Within certain limits, such inequalities may be taken care of by the dynamic power of the ship to climb or descend by the use of the elevators and the thrust of the propellers.

During flight, the consumption of fuel causes the airship to become light unless gas is permitted to escape. With hydrogen, valving has been done without hesitation because of the low cost of the gas; but with helium, such valving would be very expensive, and to compensate for the weight of fuel burned and to avoid the necessity of valving gas during flight an ingenious apparatus was

devised. This is the water-recovery apparatus in which the steam contained in the exhaust gases, resulting from the combustion of the hydrogen, which forms a constituent part of the fuel, is condensed. A weight of water slightly in excess of the weight of fuel consumed is recoverable in this manner.

An airship is directionally unstable both vertically and horizontally, so that constant operation of the rudders and elevators is necessary to maintain an approximately straight course. This instability does not mean, however, that failure of the elevators would inevitably result in crashing the airship. Such a catastrophe can easily be avoided by stopping the motors and dropping ballast so that the ship rises. Nevertheless, it should be remembered that an airship underway is somewhat like a steamship with a limited amount of sea room, with the difference that the dangers to navigation are below instead of to the side, and prompt use of ballast is an ever-ready means of avoiding trouble in an emergency.

The airship has the great inherent advantage over the airplane that it can land at zero speed instead of something like 40 to 70 miles per hour, as is common in modern airplanes. The landing operation consists in bringing the airship to rest, headed into the wind, over the landing field. The drag rope is then dropped and seized by the landing party and the airship is hauled down to the ground.

Recently the mooring mast has been developed, which eliminates the necessity for a large landing party. The object of the mooring mast is, however, to place the aircraft in a position to be available in all kinds of weather. Housed in a fixed hangar a cross wind of moderate velocity very effectively renders the airship "weather bound." The Germans had turn-table hangars but these structures are tremendously expensive. Mast anchoring arrangements can easily be applied to a movable base. The U.S.S. *Patoka* is fitted with a mooring mast to which our airships secure.

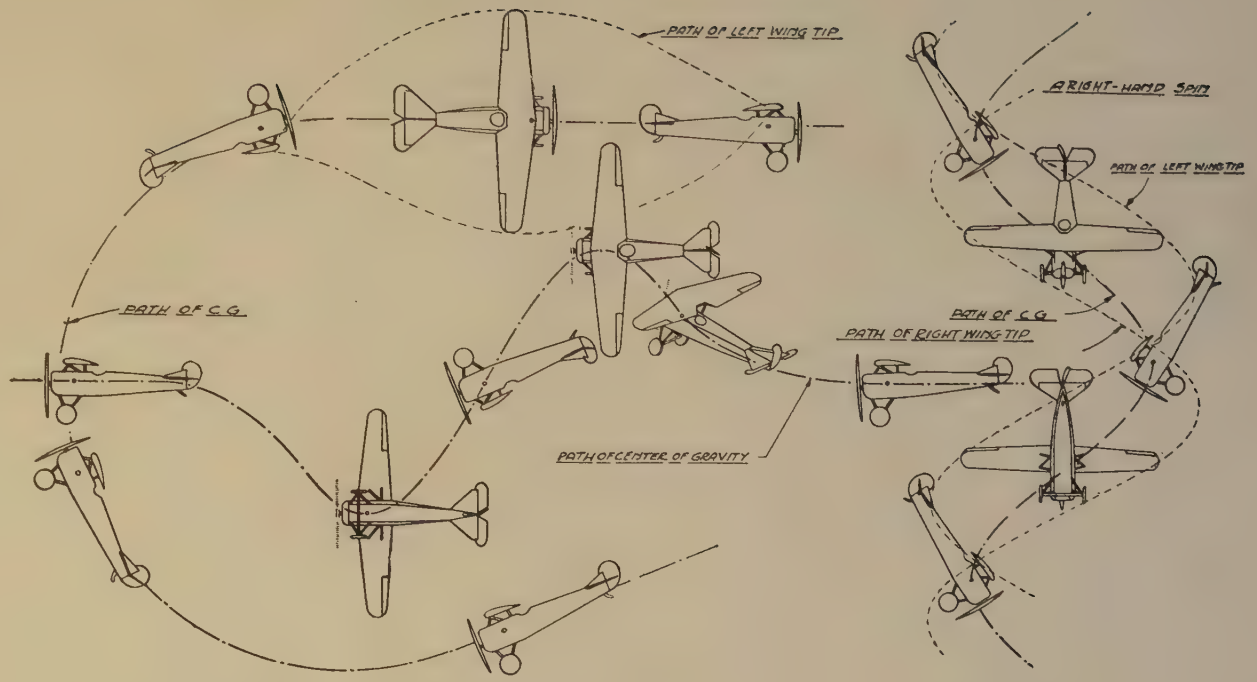
In actual practice the airship if towed by the tender does not tow from the mast on account of the undue stresses involved by the towing force taking effect at such a height above the deck. The towing line leads, as usual, through the stern chock.

The only weather condition which seriously affects airships is wind. Contrary to the popular opinion lightning is not a serious menace to them. Several kite balloons have been struck by lightning but it must be remembered that these craft are connected more directly to the earth. A stiff wind has very little effect on an airship, except in so far as it affects its progress. The steadiness of an airship in a squall has been remarked upon by the late Air Commodore Maitland in his book, *The Log of H.M.A. "R-34,"* an excerpt from which reads as follows:

7:10 P.M. Struck by a fierce squall. Heavy rain. Ship remarkably steady considering intensity of the squall.

The rain is driving through the roof of the fore car in many places, and there is a thin film of water over the chart table. The wind is roaring to such an extent that we have to shout to make ourselves heard.

Am struck by the steadiness of the ship in this squall, which is a very severe one. Beyond a gradual and very slow pitching, causing us to hold on and making everything clip about very considerably, we feel no inconvenience and not the slightest symptoms of seasickness. The sea, on the other hand, when we last saw it, was very rough and I, for one, being the worst possible sailor, would certainly be feeling horribly ill.


PATH OF LEFT WING TIP
PATH OF C.G.
PATH OF CENTER OF GRAVITY
A RIGHT-HAND SPIN
PATH OF LEFT WING TIP
PATH OF C.G.
PATH OF RIGHT WING TIP

By permission Army Air Service

THE IMMELMAN TURN THE BARREL ROLL THE TAIL SPIN

MANEUVERS

BASIC AIRPLANE MANEUVERS

The phrase "straight flight" in the flyer's nomenclature does not mean merely straightaway flight without turning or change of altitude. It means that, but in addition may mean, (2) a climbing flight at an angle not exceeding normal, (3) a downward flight at an angle not exceeding normal, (4) straightaway flight following a compass course. The terms "straight flight" and "normal flight" are often used interchangeably, but "normal flight" expressly denies any maneuver that cannot be prolonged.

Contrary to the belief of some, the maneuvers called "stunts," or acrobatics, are an important part of flying and are not by any means prohibited or discouraged in airplanes properly designed to execute them. They are distinguished from normal flight in that any one acrobatic if prolonged will result in a stall or in contact with the earth's surface at an incompatible angle. In acrobatics, also, the airplane is subjected to stresses above those of normal flight.

The ability to "stunt" is necessary to a flyer's equipment for two reasons: (1) acrobatics have their recognized place in combat flying, and (2) when thrown into abnormal positions through accident of atmosphere or necessity of emergency, a pilot must never be at a loss as to how to recover normal flight.

The maneuvers described below are basic maneuvers in flying. Some, in popular parlance, are "stunts"; all are incidental and necessary to military flying:

The zoom. A straightaway climb at such an angle that, if persisted in, the airplane will stall.

The chandelle. A sharp climbing turn, wing incidence such that, if persisted in, the airplane will eventually stall. A valuable fighting maneuver.

The dive. With or without power-on. Broadly, a height-losing maneuver at an angle beyond the normal gliding angle. More specifically, a power-on downward flight at an angle from 45 to 90 degrees from the horizontal. When perpendicular to the ground, it is called a vertical dive. When in this position, with power-on, there is a limiting speed when the drag just equals the weight of the airplane. This speed is called the "terminal velocity." The dynamic loads imposed on the airplane in recovery depend upon the speed of the plane and the abruptness with which the pilot pulls back the control column.

The loop is made by flying in a circular path in the vertical plane. (The path is more truly pear-shaped.) In few modern airplanes is it necessary to dive in order to obtain sufficient speed to carry over the top of the loop.

The vertical bank is in reality a partial or complete loop in the horizontal plane. If complete, it will be a turn of 180 degrees to reverse direction. This maneuver is sometimes improperly called a "reversed control turn," due to the fact that in it the elevators control movement in the horizontal plane and the rudder controls movement in the vertical plane.

The spiral is simply a continuous turning of the airplane in upward or in downward flight. The bank of the plane may be normal or may be vertical. In the latter case the maneuver becomes an acrobatic called a "vertical spiral." The spiral may be made downward with power off or on.

The tail spin (power on or off). The tail spin is a maneuver that is somewhat difficult to understand. An airplane which is spinning is observed to be nose down, dropping and turning in a spiral path. The speed of the drop is

comparatively slow. To spin an airplane it is necessary to pull the elevator up far enough to hold the plane at an angle of attack beyond that of maximum lift. Flying speed is rapidly lost. The rotation is started by means of the ailerons or rudder, or both. Usually, the airplane requires that the rudder be held over for the duration of the spin, although it is possible in some planes, once the spin is started, to continue without further use of rudder. To come out of the spin it is necessary to put the rudder amidships, and to decrease the elevator angle, that is, push the stick forward. This motion is an exception in airplane control, for it is quite against the natural impulse. To pull back on the stick, however, would only serve to hold the plane in the spin. When the stick is pushed forward the plane stops spinning, and remains nose down, picking up speed in a straight dive until the pilot pulls it out.

The barrel roll is, in result, a spin of one turn in a horizontal plane, with power on or off. In this case it is necessary to use all three controls to complete the maneuver. The most maneuverable planes will roll twice, or even more, before stalling.

The reversement is a much used maneuver in changing direction. It consists of half a roll and half a loop. With high powered planes it is possible to do half a loop first and roll at the top. In the first case the plane loses altitude; in the second, altitude is gained, which makes it highly useful in combat. The latter was first used by the German pilot Immelman and for that reason is known to pilots as the "Immelman turn."

Inverted flight. The airplane is flown upside down, a recognized maneuver of modern fighting planes. In the varied and rapidly changing phases of combat, the uses of this maneuver are many. In inverted flight the action of all control surfaces is reversed, considering the direction of movement of the controls themselves. The forces of sustentation over the wings are reversed, as is every stress and strain throughout the airplane. The pilot is hanging head down, held to his seat by the safety belt.

Courtesy Bureau of Aeronautics, Navy Department

THE U.S.S. "LOS ANGELES" AT PANAMA

CHAPTER IV

TYPES AND MISSIONS OF NAVAL AIRCRAFT

DESIGNATION

In naval aviation each aircraft squadron or group is assigned a designation which shows the type of service performed, the permanent numerical number of the group, and the fleet, force, station, or naval district to which the group is assigned.

The system consists of (a) class designation, (b) squadron identification number, (c) assignment letter.

(a) Class designation

	Heavier than air	Rigid airship	Nonrigid airship	Kite balloon and balloon
O—Observation	VO	.....	ZNO	ZKO
F—Fighting	VF	.....	.....	.....
T—Torpedo and bombing	VT	.....	.....	.....
S—Scouting	VS	ZRS	ZNS	.....
P—Patrol	VP	ZRP	ZNP	.....
J—Utility	VJ	.....	.....	.....
N—Training	VN	ZRN	ZNN	ZKN
X—Experimental	VX	.....	.....	.....
B—Bombing	VB	.....	.....	.....

(b) Squadron identification number

Each class of squadron will have a squadron identification number beginning with 1 and continuing in numerical series. Example—VO-1, VO-2, VO-3, ZKO-1, etc. This class designation and identification number never change, and are similar to the fixed identification numbering of all naval vessels of all types.

(c) Assignment letter

In order to indicate the assignment of each squadron, an assignment letter will follow the squadron class designation and identification number. This assignment letter may be changed as necessary in case a squadron is transferred from one unit to another.

B—Battle fleet.
S—Scouting fleet.
A—Asiatic fleet.
F—Fleet base force.
C—Control force.
D—Naval district (to be followed by district number).

M—United States Marine Corps.
R—United States Naval Reserve.
X—Experimental.
U—United States fleet (further assignment to unit of fleet not yet made).

By combining (*a*), (*b*), and (*c*), the complete designation of the squadron is obtained.

Examples—

VO-1B, "Airplane Observation Squadron One, assigned to Battle Fleet."
VT-5D14, "Airplane Torpedo Squadron Five, assigned to Fourteenth Naval District."
ZKO-1M, "Kite Balloon Observation Squadron One, assigned to U. S. Marine Corps."

The individual aircraft within the squadrons do not carry the complete squadron designation, but carry an abbreviated form, consisting of a number, letter, and a number. The first number is the squadron permanent designating number, the letter indicates the mission of the squadron, and the last number shows the number of the aircraft within the squadron.

Examples—

9F16, "Combat Squadron Nine, airplane number sixteen."
2S10, "Scouting Squadron Two, aircraft number ten."

If the squadron is of Marine aviation an "M" follows the squadron number, as *VT-1M.* Each plane in the squadron is also numbered. For identification the tactical designation is painted on the fuselage, and consists basicly of two figures with a class letter between. For example, the second plane of the first torpedo squadron is marked *1-T-2.* An arbitrary sign is made for the observation squadron because of the confusion which might result from the similarity of "O" and "Zero." The second plane of observation squadron five, for example, is marked 5/2. Marine Corps airplanes have a circle around the class letter. The sixth plane of the second Marine fighting squadron would bear the mark 2-Ⓕ-6, and fifth plane of third Marine observation squadron 3-⊙-5.

An addition of letters may be made to designate the name of the station to which planes belong. If the station name consists of two words the initial letters are used, as 4 SD-F-10 (San Diego). Where the name is of only one word the first and last letters are used.

Class Designation

The designating letters given in table (a) above are used in referring to each class in general. The addition of a number and a letter denotes the design and the maker. Example: *VTN* and *VT2N* are the first and second Navy designs of a manufacturer's torpedo plane. If major alterations are made in a model, such as a different engine, or other modifications which are not of a character to change the design, the modified models are designated by adding another number, such as *VTN-1, VT2N-2,* etc.

The designations, seaplane, landplane, flying boat, etc., are used after the model letters where necessary to describe the aircraft more definitely.

In arriving at the *Navy's* class designations, the various designers or contractors are assigned key letters as follows:

The manufacturer's letters are:

A—Atlantic Aircraft Corporation
B—Boeing Airplane Company
C—Curtiss A. and M. Company
D—Douglas Company
E—
F—
G—
H—Hall Aluminum Aircraft Corporation
I—
J—
K—Keystone Aircraft Corporation
L—Loening Aeronautical Engineering Corporation
M—Glenn L. Martin Company
N—Navy Department
O—
P—
Q—Fairchild Aviation Corporation
R—Ford Motor Company
S—Sikorsky Manufacturing Corporation
T—
U—Chance Vought Corporation
V —
W—Wright Aeroplane Corporation
X—
Y—Consolidated Airplane Corporation
Z—

The "V" is often omitted, leaving an abbreviated designation, as *F3W* (third design Wright fighter).

Before the order establishing this system of designations came out the maker's designations were somewhat arbitrary. Often they contained the initial of the maker and the Navy class designation, for example: DT (Douglas torpedo). The designations in use when the order came out were not changed. Many models, therefore, bear the old designations.

The designation of airplanes of an experimental design is prefixed by the letter "X." Airplanes so designated retain the prefix while in service in order to indicate that such airplanes were the first of that experimental design series. *XF2B-1* indicates that such an airplane is the first of a new series of experimental fighters manufactured by the Boeing Airplane Company, although this design is the second fighter design to be adopted by the Navy. When the new airplane design is accepted for service use and put into production, the prefix in the designation is dropped for the production airplanes.

GENERAL DISCUSSION

Monoplanes. As has been pointed out earlier in this book, monoplanes do do not lend themselves well to general naval usage. The monoplane is undoubtedly more aerodynamically efficient than a biplane of the same total wing area. Its excessive span, however, practically precludes its use aboard ship, and it cannot be made as structurally strong as the multiplane. It is well adapted for shore-base transport planes.

Biplane versus multiplane. The biplane is to date the happy compromise between the efficient monoplane and the too inefficient multiplane. (The biplane is also of course, strictly speaking, a "multiplane.") Although several military triplanes have been built, their use has been discontinued due: (1) to structural difficulties; (2) to the fact that the "biplane effect" greatly reduces the lift of the inner wings; and (3), to the excessive heights resulting from the superimposition of wings. ("Biplane effect" is the interference by one lifting surface

with the negative wind pressure or "vacuum" acting on the lifting surface immediately below it.)

For the reasons noted above, we find the great majority of service types are biplanes.

Other than this, the types are many and varied, and change from year to year as improvements are made or new methods of construction are adopted in the airplanes themselves, in power plants, or in landing or flotation gear.

All modern naval planes are of metal construction; some with fabric fuselage and wing covering, some of all-metal surfaces.

The types vary widely as to overhang, stagger, sweepback, dihedral, cathedral, etc. Some are single-engine, some two-engines, some triple-engines. The majority of modern naval planes are powered with air-cooled engines, these engines varying in power according to the work required of the airplane.

It is beyond the scope of this book to cite in detail the differences in service types, except as may be presented in a simple tabular form.

Oleo gear. The Bureau of Aeronautics has in recent years used the oleo landing gear in constantly increasing amount. The term "oleo" embraces a number of variations; any landing gear including oil in its shock-absorbing elements is an oleo gear. Some of the most conspicuous types are:

(1) Oil plus a steel spring—notably the Boeing gears.
(2) Oil plus rubber in compression—notably the Curtiss gears.
(3) Oil plus air—notably the Cleveland Pneumatic-Glenn L. Martin gears.

This covers the combinations of the different elements, but there are variations in each of these classifications as to what percentages of shock absorption is done by the oil action, time at which the air, spring, or rubber "cuts in," direction of action of the oleo, etc. In the first two types above, the oleo is designed to absorb shock on the up stroke of the gear whereas in the third type the oil does not perform its function on the up stroke (as a valve opens, allowing practically free flow of the oil and the shock is taken on the air cushion), but on the *down* stroke—the rebound—the oil valve closes and holds the rebound to a very slow motion only, governed by the size of the orifices through which the oil must flow.

The first demand for oleo landing gear came from the aircraft carrier *Langley,* where there was urgent necessity for a method of shock absorption that would be very efficient, absorb very violent shocks in a smooth, uniform, yet forceful way, letting the plane down easily into the arresting gear, and yet at the same time have no undesirable rebound feature. Not alone on the carrier, however, is such a landing gear highly desired; such a gear also meets a long-felt need of planes operating from landing fields, whether military or commercial. Elastic rubber cord was formerly used for shock absorption. In addition to its resiliency, rubber has the characteristics of varying its nature, particularly with age, and it is necessary to renew frequently the shock-absorbing elements with new rubber—new not only in the sense of never having been used, but also new in the sense of having been recently manufactured, for the rubber deteriorates in storage as well as in service. To take care of this, it has been necessary to mark rubber shock-absorber cord with colored threads signifying the time of manufacture and to issue instructions to the service to use cord not over one year old. The charac-

Table D

CHARACTERISTICS - WEIGHTS - PERFORMANCE - NAVY SERVICE AIRPLANES 1928

Class	Model	Type	Engines			Weights			Speed		Endurance		Climb in 10 min.	Service ceiling	Wing area	Span		length	height	Chord	Gap	Dihed.	Sweep back	stagger	Class
			Model	HP	RPM	empty	useful load	Per HP	max	stall	Full speed	cruising				upper	lower								
VN	*NY-2*	Seaplane Single Fl.	Wright R-790	220	1800	2088	699	12.70	96	48.3	2.7	3.7	5000	12300	370	40′	40′	31′–5″	1–10″	5′	5′	0	0	28″	*VN*
VN	*NY-2*	Landplane	do	do	do	1801	699	11.30	98	45.8	2.7	4.3	7200	17000	do	do	do	27′–1″	9′–11″	do	do	do	do	do	*VN*
VO	*O2U-1*	Seaplane Single Fl.	Pratt-Whit R-1340	410	1900	3641	1300	8.88	146	58.5	2.4	7.1	10200	20500	320	34′–6″	34′–6″	28′–6″	11′–4″	5′–5″	5′–5″	0	4°.75	17″.25	*VO*
VO	*O2U-1*	Landplane	do	do	do	3389	1300	8.26	150	56.4	2.4	8.0	13500	21000	320	do	do	24′–7″	10′	do	do	0	do	do	*VO*
VO	*OL-8*	Amphib.	do	do	do	3290	1430	11.50	120	56	2.6	5.6	7100	4350	504	45′	45′	34′–9″	12′–9″	6′	5′–11″	2°.75	0	12″	*VO*
VF	*F2B-1*	Landplane	do	do	do	1998	816	6.85	158	59	1.3	4.1	13000	22000	243	30′–1″	24′–3″	22′–1″	9′–3″	6′ to 5′	4′–10″	0	0	25″.5	*VF*
VF	*F6C-4*	Landplane	do	do	do	1980	805	6.80	155	58	1 3	4.0	15000	23000	252	31′–6″	26′	22′–6″	9′–8″	6′ to 4′	4′–6″	1°.5	12″	38″.5	*VF*
VS	*T3M-1*	Landplane	Wright T3B	575	1900	5460	3532	15.60	109	54.2	6.8	13.4			848	52′–4″	56′–7″	41′–9″	15′–2″	8′–3″	8′–6″	1°.5	0	0	*VS*
VT-VB	*T3M-2*	Landplane	Packard 3A-2500	770	2000	5806	3704	39.00	109	55.2	2.0	3.7	3400	8000	883	56′–7″	56′–7″	41′–4″	15′–2″	8′–3″	8′–6″	1°.5	0	0	*VT-VR*
VJ	*TA-1*	Landplane	Three Wright R-790	3×200	1800	5460	3600	39.60	116	62	3.3	5.3	5600	12000	630	63′–5″	0	49′–1″	12′–7″	12′ to 5′	0	1°.0	0	0	*VJ*
VP	*PN-10*	Boat	Two Packard 1A-1500	2×525	2100	10060	8934	18.00	114	66	11.1	17.8	2500	4500	1217	72′–10″	67′–2″	49′–2″	16′–9″	9′	9′–4″	0/3°	0	0	*VP*

teristics of rubber in tension are so variable and unsatisfactory that the first step was toward shock absorption by means of rubber in compression; i.e., the "rubber doughnut" type. The next step was from the rubber compression to the oleo gear.

The Navy has acquired these oleo gears and is now using them in large quantities on: (*a*) its pursuit planes; (*b*) all of its bombing planes; (*c*) most of its observation planes. Some of the advantages of the oleo gear over the old type of rubber gear are:

(1) Less maintenance trouble due to less changing of shock absorbers. Some of the oleo gears go for months at a time without requiring any attention or "make up" of oil.

(2) A "cleaner" installation, less fag ends, less resistance, consequently better performance.

(3) Weights have been practically the same, or slightly less than the old type rubber strung gears.

(4) Practically no rebound except on very hard landings.

(5) Small angle of incidence on the ground, making for easier take-off and taxiing. (This only applies where the oleo absorbs shock on the up stroke.)

From the data of table D, a second one may be compiled, showing the *present* general types and tendencies in the service, as follows:

TABLE E

Class	Mission	Approx. Dimensions	Approx. Weight	Approx. Endurance	Approx. Speed	Approx. Ceiling	Crew	Engines / Power
VS	Scouting	Span: 55′ Length: 43′	9500 lbs.	10–15 hrs.	110 mph	8000 ft.	3	one / 500–800 HP
VP	Patrol	Span: 75′ Length: 50′	20000 lbs.	15–20 hrs.	115 mph	5000 ft.	6–8	two / 1100 HP
VT VB	Torpedoing Bombing	Span: 60′ Length: 43′	10000 lbs.	5 hrs.	110 mph	10000 ft.	3	one / 800 HP
VO	Observation	Span: 40′ Length: 25′	3800 lbs.	8 hrs.	140 mph	20000 ft.	2	one / 400 HP
VF	Combat Light Bombing	Span: 32′ Length: 25′	3000 lbs.	4 hrs.	160 mph	25000 ft.	1	one / 400 HP
VN	Training	Span: 40′ Length: 28′	2000 lbs.	4 hrs.	100 mph	15000 ft.	2	one / 220 HP
VJ	Utility Mail Transport	Span: 65′ Length: 50′	10000 lbs.	5 hrs.	115 mph	12000 ft.	3–30	three / 600 HP

MISSIONS

The general service is far more interested in what the various types of airplanes are designed to do than in their differing technical details.

We are indebted to Rear Admiral Moffett for a clear exposition of these various *missions,* which are as follows:

Gunnery spotting planes are in effect high observation posts for gun spotters. The duties of the spotter in the plane are identical with the duties of the spotter in the spotting top of the battleship. The important distinction is that the spotter in the plane can often see clearly what the spotter on the ship cannot see at all.

Scouting airplanes are merely mobile look-out stations which extend the range and permit them to observe clearly what is going on beyond the horizon, or behind opposing advanced forces of an enemy fleet.

Bombing airplanes perform exactly the same basic function that guns perform: to throw a destructive projectile against the enemy. The important distinction between projectiles propelled from a gun, and those propelled by an aircraft engine, is that the ship using bombing aircraft is able to strike the enemy at approximately ten times the range that is possible with ordinary gun fire. Heavy bombs are equivalent to major caliber gun projectiles; light or intermediate weight bombs are equivalent to minor or intermediate caliber gun projectiles. Bombing operations against submarines have of course the same objective as have depth charges dropped from destroyers or other surface vessels. Bombs which drop in the danger space near to the sides of ships and explode beneath the water are in reality mines. Gun projectiles, aerial bombs, depth charges, mines, all have the same objective at sea—the destruction of enemy ships.

The **torpedo plane** is essentially merely a mobile torpedo tube. The conventional torpedo vessel, which uses launching tubes affixed to her decks, can deliver a torpedo attack only by placing herself and her entire ship's company in danger of destruction by defending gun fire. If, however, the torpedo vessel can use torpedo planes in place of the conventional fixed launching tubes, the ship and most of its crew lie well out beyond opposing gun range, while she sends a few men in *planes* to attack; thus in effect exposing only the torpedo tubes and their crews to danger—while the ship and the ship's company remain safely beyond gun range. An attack delivered in this manner greatly reduces the number of men and the value of material placed in jeopardy; and at the same time greatly increases the difficulty of the problem which confronts the defending forces. The underwater blow of the torpedo is as a general rule more destructive than that of the above-water blow of the gun. The gun has retained its position as the principal weapon of ships largely because of its superiority in accurate effective hitting range, largely because of its ability to destroy torpedo vessels before they could advance to within effective striking range.

Smoke laying aircraft are employed for exactly the same reasons that smoke laying destroyers and cruisers are employed, the only important distinction being that when aircraft are used to lay smoke screens instead of sending in valuable cruisers or destroyers, the job is done quicker; the target offered to the enemy is smaller, faster, and more difficult to hit; and only a small number of men

is placed in danger, instead of a whole ship's company. The use of airplanes in smoke-screen making opens tremendous possibilities in all manner of fleet tactics, both in attack and defense.

Fighting aircraft have exactly the same mission to perform as have anti-aircraft guns mounted on the decks of surface ships. Both fighting airplanes and anti-aircraft guns are designed to destroy enemy aircraft. The important distinction is that the fighting aircraft projectiles can reach enemy aircraft at ranges and in many conditions where the conventional anti-aircraft gun is utterly impotent. It appears to be well established that fighting airplanes are a far more effective defense against air attack than are anti-aircraft guns.

There has recently been developed new smoke-making apparatus for use with light planes, which is easily and quickly attachable to the bomb racks of any type of plane fitted to carry bombs. For example, such apparatus has been fitted to a standard single-seat fighter and has demonstrated the entire practicability of laying a complete smoke curtain a mile and a half long at a speed of 150 miles per hour with a single plane, of this type. As we gain experience in actual operations in the fleet at sea, and have opportunity to study the matter more deeply, it becomes ever more apparent that there is no general classification of service in the United States Navy that is so essentially and comprehensively *naval*, in the broader sense of the word, as is naval aviation. It becomes ever more apparent as we gain experience that the airplane *does not* and *cannot* perform any new basic function in war which has not been performed in some manner or other for years past by other naval agencies. At the same time it becomes ever more apparent that there is no type of vessel, and no class of naval service whose effectiveness in war is not greatly enhanced by the coöperation of aircraft in one form or another.

To summarize. Airplanes would be used for bombing combatant ships, strafing attacks against light forces, torpedoing capital ships, laying smoke screens, tactical scouting, observation of gun fire, destruction of enemy planes, early information of the enemy even at great distances from the fleet, locating and attacking enemy combatant ships operating on our lines of communication, in attacks on shore objectives.

The airplane in naval operations is at once a vehicle, a high observation post, a gun, torpedo tube, a depth charge projector, a mine layer, and a smoke screen layer. The field of naval aircraft operations at sea is as wide as the Navy itself, no wider. Aircraft have an important application in the operation of all ships, and all forces afloat—in all classes of service. We may speak of aircraft carriers in much the same comprehensive sense that we speak of gun carriers or torpedo carriers or mine layers.

AIRSHIPS

The rigid airship (ZR) has great inherent possibilities for open sea service, particularly in patroling and scouting our sea areas, because of its great endurance and long range. Its use is principally restricted by the great cost of handling and mooring equipment and ground crews. The development of methods for reducing the cost of handling and maintenance is an even greater problem than the construction of the ships themselves. It is to the solution of this problem

that the principal effort in the airship activities of the Navy were directed up to 1928. These efforts produced most gratifying results, and led to the belief that the inherent difficulties and high cost of rigid airship operation had been greatly exaggerated.

What the future holds for the large rigid airship the future alone knows. The possibilities are great, but the further obstacles which may arise have yet to be determined by greater experience.

Great Britain has built two rigids of 5,000,000 cubic feet, having a radius of over 7,000 miles. These ships carry twenty-five machine guns placed at various points on the sides, top, and ends of the envelope. Several 1- or 2-pounder anti-aircraft guns are placed on the top. This protection is probably not sufficient to ward off attack by bomb. The next development will be a provision for carrying four or five fighting planes within the under inclosure of the ship's structure.

Under the provision of reasonable protection, the fundamental characteristics of the rigid airship make it particularly useful for the following missions:

(a) Reconnaissance and scouting.
(b) Prolonged observation.
(c) Trans-oceanic escort.
(d) Anti-submarine patrol.
(e) Coastal patrol.
(f) Mine field searching.
(g) Carrying heavier-than-air aircraft.
(h) Transporting material and personnel.
(i) Bombing.
(j) Fleet control.
(k) Communicating with detached and distant expeditions.

The Airship "ZR-3" ("U.S.S. Los Angeles")

General Characteristics

Length, 658 ft.
Diameter, 92 ft.
Height, 100 ft.
Gas capacity, 2,470,000 cu. ft.
Number of gas cells, 14.
Total lift, inflated with helium gas, about 148,000 lbs.
Dead weight, about 85,000 lbs.
Speed, maximum, 75 mi. per hr.
Speed, cruising, 60 mi. per hr.
Horse-power, 2,000, five engines of 400 h.p. each
Crew, 35 officers and men.

This airship was constructed by the Zeppelin Airship Company at Friedrichshafen, Germany, for the United States government as a replacement for two airships of smaller size to which this country was entitled at the close of the World War. The *ZR-3* is designed as a commercial airship, and has accommodations for twenty passengers.

The flight of the *ZR-3* to this country from Germany was made on October 12 to 15, 1924, starting at Friedrichshafen and terminating at the Naval Air Station, Lakehurst, N.J. A distance of 5,066 miles was covered during the flight

in 81 hours and 17 minutes, or at an average speed of approximately 62 miles per hour. The *ZR-3* is housed in the airship shed at the Naval Air Station, Lakehurst, N.J. She is used for experimental and development work in connection with airships, and has proved invaluable in giving our personnel the necessary experience in airship operation. She cannot, by international agreement, be used for war purposes.

"ZR-4" and "ZR-5"

During the year 1928, contracts were let for rigid airships *ZR-4* and *ZR-5*, each of 6,500,000 cubic feet capacity.

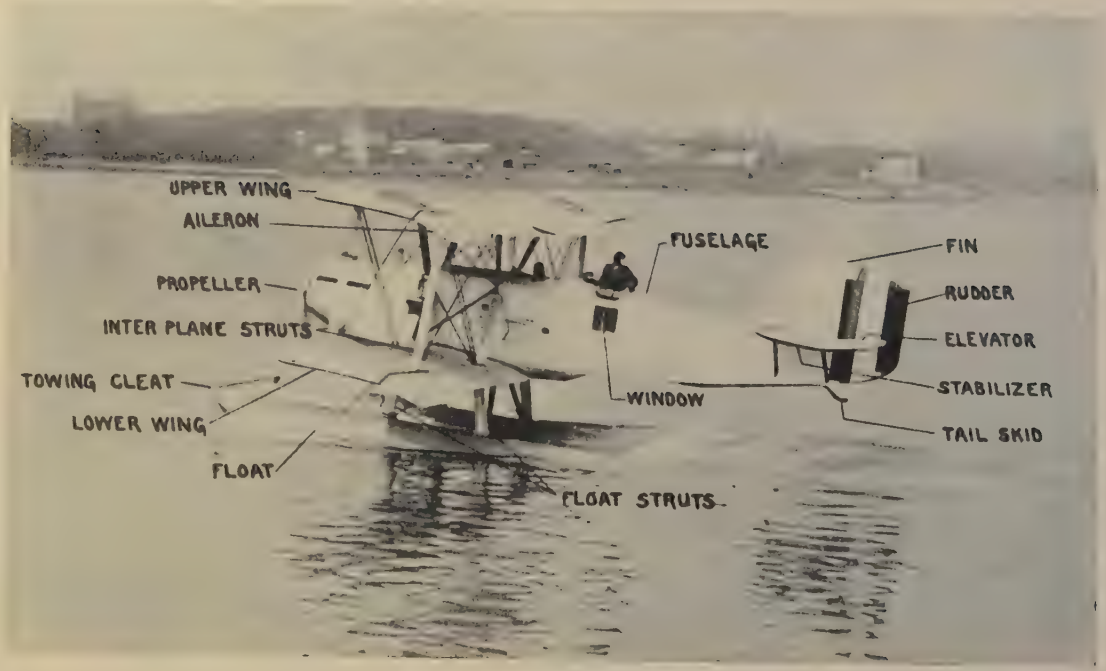
The announced plans for these rigid airships call for each to carry a number of small airplanes. These planes, normally housed in the interior of the airship, will be launched and landed aboard in mid-air. The method of landing them is, in general, a "hook-on" method.

ZK (Kite Balloon)

The kite balloon, while extensively and effectively used as an observation and spotting platform by land forces during the war, did not demonstrate its adaptability for use with mobile naval forces. The facilities for handling, housing, and inflating which can be provided ashore do not exist afloat, and cannot be incorporated into the design of ships without seriously disarranging the plans of providing accommodations for other types of aircraft of recognized value to the fleet.

A far more serious disadvantage was the fact that the "kites" effectively located each of our battleships to the enemy, long before our hulls were visible above the horizon. This disadvantage was fatal and caused their absolute abandonment for fleet use.

During the winters of 1919-20 and 1920-21 the Atlantic Fleet Kite Balloon Squadron, ordinarily based at the Naval Station, Hampton Roads, was transferred to Guantanamo and established at Fisherman's Point, from which base occasional exercises were conducted with battleships of the fleet. These activities were abruptly suspended in March, 1921, by the commander in chief following a disastrous morning's operations, resulting in the loss of two balloons, two deaths, and numerous injuries to the flying personnel.


UPPER WING
AILERON
PROPELLER
INTER PLANE STRUTS
TOWING CLEAT
LOWER WING
FLOAT
FUSELAGE
WINDOW
FIN
RUDDER
ELEVATOR
STABILIZER
TAIL SKID
FLOAT STRUTS

CURTISS *CS-2*

CHAPTER V

AIRCRAFT POWER PLANTS

Every heavier-than-air craft flies on its engines. The fundamental principles of flying have been fairly well known for many years. Four hundred years ago Leonardo da Vinci wrote a treatise on human flight and gliding experiments comparable to those of the Wright brothers. It remained for the twentieth century development of the internal-combustion engine to realize the age-old dream of flying.

The trans-oceanic flights of Lindbergh, Chamberlin, Byrd, Kingsford-Smith, and others during the past are triumphs of personal skill and daring, but they are of real importance to aviation development as a useful agent in the world of affairs because they demonstrate the reliability, dependability, and efficiency of aircraft equipment of today. The Navy takes pardonable pride in the fact that the engines and power-plant equipment which contributed so largely to the success of all trans-oceanic flights from this country have been developed under naval supervision with naval funds; that engines of this type had been in extensive use as standard equipment in naval seaplanes for more than four years; and that the engines used in these flights were exact duplicates in all respects of equipment which had been standard in the Navy for more than a year.

In the practical design of aeronautical engines, too often in the past, the engine designer neglected the viewpoint of the airplane designer. Neither can afford to ignore the other's problems. As in every major engineering problem the completed structure is a compromise between widely divergent possibilities. From the aerodynamical standpoint the engine for an airplane should have a minimum frontal area of such shape as to permit streamline cowling to reduce the air resistances encountered at high speeds. It is desirable that the radiator size be reduced to a minimum for the same reason. It is highly desirable that the engine interfere as little as possibly with the pilot's vision. To permit of easily balancing the completed airplane, it is desirable that the engine be as short and compact as possible. As in the case of water propellers, it is necessary to limit the tip speed of the propellers, hence either the diameter of the propeller or its revolutions per minute must be reduced. A large propeller turning slowly is far more efficient than a smaller propeller turning at higher speed.

Most important of all design considerations is the weight. Modern airplanes fly with wing loadings ranging from 5 to 24 pounds per square foot of supporting area and with power loadings ranging from 6 to 25 pounds per horse-power. Useful loads, including the fuel and pilots, vary from 40 to 100 per cent of the total dead weight of the empty airplane. Manifestly every pound saved in power plant may be added to the useful load. The power plant requirements for an airplane may be summarized:

(1) Maximum power per unit of weight.
(2) Maximum reliability.

(3) Economy and efficiency.
(4) Maximum attainable safety from fire.
(5) Minimum frontal resistance.
(6) Minimum interference with visibility.
(7) Minimum weight per horse-power.
(8) Economy and ease of maintenance.

To attain maximum power per pound of weight, designers have increased engine speed and brake mean effective pressures. The first engine flown by Wright brothers was a four-cylinder water-cooled engine developing 32 h.-p. at 1,200 r.p.m. It weighed 180 pounds dry, or about 5 pounds per b.h.-p., but with radiators and accessories it weighed 7 or 8 pounds per b.h.-p. The brake mean effective pressure with a total displacement of 240 cubic inches was about 90 pounds per square inch. The first increase in power was secured by running up to 1,600 r.p.m., at which speed the engine developed about 39 h.-p.

For several years it was not considered desirable to run engines above 1,600 r.p.m. The loss in propeller efficiency more than offset the gain in power. Gearing down the propeller speed from the crankshaft speed proved impracticable. Gear designers could not produce reliable gears within the weight limitations. The next possibility of increasing engine power per pound of weight lay in increasing the brake mean effective pressure, that is to say, the power developed per cubic inch of piston displacement. By improved valve operation, increased valve areas, and better design of exhaust and intake passages the average brake mean effective pressure was raised to about 112 pounds per square inch. Next, brake mean effective pressure was increased by raising the compression ratio, that is the ratio volume above the piston at the bottom of its stroke to the volume remaining above the piston at the top of its stroke. From about 4.5 to 1 the standard compression ratio has been raised to 5.5 to 1. This is about the limiting ratio using regular aviation gasoline. Higher compression ratios are made possible by the use of special or doped fuels.

At present engines developing brake mean effective pressures close to 140 pounds per square inch are in general service. As this seems near the practical limit attention has reverted to crankshaft speed. Propeller improvements permitted increasing crankshaft speed with direct connected propellers to 2,000 or perhaps 2,200 r.p.m. with some gain in useful power. This was not enough. Racing automobiles have operated successfully for several years with the revolutions up to 5,000 and even 5,500 r.p.m. Just as in the history of marine turbines, gears had to come. Recent airplane engine gears weigh not over 0.25 pound per horse-power, and have passed satisfactorily a 100-hour endurance test.

Closely connected to weight per horse-power is the specific fuel consumption, that is, the weight of fuel consumed per b.h.-p. per hour. Manifestly it is useless to reduce the engine 10 or 20 pounds if each hour that engine consumes 10 or 20 pounds of fuel more than a heavier engine consumes. Efficient marine turbine installations probably operate at about 1 pound of fuel per b.h.-p. hour. The best theoretical specific fuel consumption is slightly below 0.4. Diesel engines are noted for their inherent economy. The best Diesel-type submarine engines usually consume something over 0.5 pounds per h.-p. hour. The average aeronautical engine,

operating on the Otto cycle, consumes about 0.52 pounds per h.-p. hour, and efficient aeronautical engines operate on as little as 0.43 pounds per h.-p hour.

From a flier's standpoint reliability is the chief requirement of an aeronautical engine. Closely connected with reliability on the basis of cost per flying hour is engine durability. The impression is general that in aeronautical engines weight has been cut to such a degree that reliability is sacrificed. Contrary to popular belief, it is not necessary to load down an engine with hundreds of pounds of cast-iron to make it reliable and durable. Frequently an automobile engine runs for 8,000 or 10,000 miles without any mechanical difficulty. How far would that automobile engine travel on a race track, running with the throttle wide open? The average power developed by an automobile engine is scarcely one-fourth of its full throttle power. Take into consideration the sudden and extreme changes in conditions encountered by airplane engines, and remember that they normally operate at above 90 per cent of their maximum full throttle power and do this on the average for 75 or 100 hours. Then the performance of the modern airplane engine becomes apparent. Often an airplane engine runs several hundred hours, during which time the airplane travels many thousand miles.

Fuel. Higher compression ratio has been mentioned as a means employed to increase mean effective pressures. Thermodynamics teaches us that the maximum theoretical efficiency of any internal-combustion heat engine depends on the compression ratio. That is the secret of the Diesel cycle. Unfortunately engines operating on the Otto cycle are limited in compression ratio by the pressure at which the fuel charge present in the form of an inflammable mixture with air is raised to its flash point temperature by the pressure. When this occurs the condition known as detonation is set up similar to the so-called spark or carbon knock caused in an automobile engine. Whereas the best aircraft engines will not operate properly on gasoline at compression ratios above 5.5 to 1, automobile engines turning at 5,000 r.p.m. have operated with the compression ratio up to 7 to 1. Conditions are much less severe, however, than in aeronautical practice.

In the effort to increase brake mean effective pressures and improve fuel economy, special fuels have been developed for operation at higher compression ratios. A mixture of gasoline and benzol has been used on a large scale. This blend remains the standard of comparison for other fuels but is open to severe objections. In the first place benzol contains ingredients required in the manufacture of high explosives. It would not be available in sufficient quantities in time of war. Secondly, the freezing point of benzol is comparatively high and in cold weather a heavily doped mixture becomes a menace to successful operation.

Blends of gasoline and anhydrous ethyl alcohol have proved suitable for service but have several disadvantages. If exposed to the atmosphere the alcohol tends to combine with the ever-present moisture and to separate from the gasoline. It is difficult to secure proper carburization over the range of engine operation and engines using alcohol blends are difficult to start.

The so-called ethyl fluid, a tetraethyl lead derivative, produced originally by the General Motors Research Laboratories, was adopted by the Navy and has been used very successfully.

Much remains to be done before the average compression ratio can be raised appreciably above the limits now fixed.

Ignition. Next to fuel comes the question of ignition. Magnetos are now used exclusively. The battery-generator ignition was applied to some of the larger engines, but has not been retained. Magneto ignition is used because of its simplicity. In general it may be said that battery ignition makes the engine easier to start, as it insures a maximum spark intensity at the low rotating speeds attained by hand and inertia starter cranking. On the other hand proper average regulation of the generator is difficult to maintain; the battery is heavy and is subject to damage through rough handling or improper care. Service magnetos do not give sufficient spark intensity to start an engine easily, but are simpler and far more compact than battery-generator systems. To insure easy starting, auxiliary or "booster" magnetos are installed, usually manually operated by the pilot.

The chief original drawback to the use of magnetos was the unreliability of the American-made instruments. They were not sturdy in structure; they were electrically and mechanically defective in comparison with foreign-made magnetos, of which the best came from Switzerland.

These difficulities have been entirely overcome. American companies are now supplying aviation with magnetos that are as good or better than any that may be obtained in the foreign markets. They meet the requirements of the aviation magnetos, which may be summarized:

(1) Intensive and consistent spark.
(2) Reliability of coil insulations, particularly in the tropics.
(3) Rugged construction.
(4) Absolute reliability of bearings and their lubrication.
(5) Maximum reliability of electrical operation.
(6) Ease of adjustment and repair.

Lubrication. The lubrication of aeronautical engines is more or less standardized. Oil circulated under comparatively high pressures is depended upon not only to lubricate the bearings but also to conduct away from them a considerable portion of the heat developed. Flooding the working parts with oil has the disadvantage of introducing various abrasive particles into the bearings but seems to be the only practical way of handling the excess heat.

Cooling. The greatest single achievement in aviation since the close of the World War has been the high development of the radial air-cooled engine.

The original airplane engines were water-cooled. Various air-cooled engines have been developed. The most successful of the early types were the rotary engines used chiefly for pursuit planes in the early stages of the World War. Then the demand for greater power, improved visibility, and increased reliability drove designers to the 8-cylinder, V-type of water-cooled engine. Not until the pressure of war production fell off after the Armistice could designers find time to take up again the air-cooled principle. The elimination of water jackets, radiators, piping, and the necessary water effects a saving in weight much to be desired. Moreover, cooling systems are a frequent source of maintenance and operating difficulty. The Royal Air Force found that under extremes of temperature such as the cold of northern Russia and the heat of Mesopotamia the air-cooled engine stood up better than the water-cooled engine. Following considerable experimen-

tation the Bureau of Aeronautics adopted a policy of using air-cooled engines exclusively for all powers.

Mechanical details. The discussion of mechanical details could be extended without limit. First is the question of engine type as relates to cylinder arrangement. At one extreme we have the very long airship engines with six extremely large cylinders arranged in line. At the other is the very short radial having from three to eleven cylinders, all arranged circumferentially about the same crankpin. Tied up in the question is an infinite number of considerations, dynamic balance, weight and size per horse-power, exhaust and intake manifolding, lubricating, cooling, accessibility, and manufacturing difficulties.

Engines with 4- or 6-throw crankshafts must have heavy crankshafts and crankcases to secure proper stiffness. Shorter engines are inherently stiffer and lighter. However, radial engines having single-throw crankshafts require the use of a balancing counterweight. To reduce the counterweights and increase power, engines have been built with two sets of cylinders arranged radially about a 2-throw crankshaft. This construction involves the necessity of building up the crankshaft and also sets up a terrific bending force which tends to break the crankshaft. Increasing the number of crank throws to four takes us back to the original 4-cylinder engine design, in fact the 12-cylinder "W" is nothing more than four 3-cylinder radials connected together.

In the materials of construction there has been as much advance as in any other field of aeronautical design. At the present time the question of substituting for aluminum the lighter alloys of magnesium is being investigated. A saving of nearly one-fourth in the weight of aluminum parts is expected. The substitution of duralumin for steel is another possibility.

Cylinder design is one of the major subjects of engine study. Without exaggeration, almost every conceivable cylinder construction has been tried out. Starting with plain cast-iron cylinders with cast water jackets, there have been countless variations to increase strength and decrease weight.

Piston design has followed a less complicated but very interesting development. The first pistons were of cast-iron. The necessity for minimum weight to improve dynamic balancing led to the substitution of aluminum or aluminum alloys.

A recent development of the highest importance has been the adoption of the Diesel principle to high-speed aircraft engines. This development may prove epochal. In any case, it is impossible to guess at the future trend of design in aircraft power plants.

Starters. The inertia starter is used for the purpose of imparting the initial revolutions to an aircraft engine in order that it may start and run under its own power. Such a starting device is necessary on engines in order to prevent injury to personnel, such as that which occurred frequently in former days when starting was accomplished by moving the propeller by hand, and to facilitate starting in seaplanes and large landplanes.

The type of starter now used entirely by the Navy operates on the inertia principle: a heavy flywheel is turned to a speed of about 12,000 or 15,000 r.p.m. through a train of gears connected to a hand crank or other energizing means. Through another train of gears, a clutch, and an engaging dog, the energy of the flywheel is imparted to the crankshaft of the engine. This inertia type of

Table F

Navy Service Aircraft Engine Data December, 1928

Navy Department
Bureau of Aeronautics

Name and Class	No. Cylinders	Cooling Type	Wt. Lbs.	Lgth. In.	Wdth In.	Ht. In.	Dia. In.	HP	RPM	Bore and Stroke	Cyl. Displ. cu.in.	Ignition Type	Starting	Carburetor
Curtiss D-12M	12 Vee	Water	680	56 3/4	28 1/4	34 3/4	—	435	2300	4.5″×6.0″	1145	2 Scintilla mag.	Aeromarine	2 Stromberg
Packard 3A-2500	12 Vee	Water	1220	69 3/4	29 1/4	420	—	770	2500	6.375″×6.5″	2539	2 Scintilla mag.	Aeromarine	2 Stromberg
Pratt & Whitney R-1340	9 Radial	Air	650	43 3/8	—	—	50 5/8	410	1900	5.75″×5.75″	1340	2 Scintilla mag.	Eclipse	1 Stromberg
Pratt & Whitney R-1340B	9 Radial	Air	675	43 3/8	—	—	50 5/8	450	2100	5.75″×5.75″	1344	2 Scintilla mag.	Eclipse	1 Stromberg
Pratt & Whitney R-1690	9 Radial	Air	765	44 5/8	—	—	54 1/4	525	1900	6.125″×6.375″	1690	2 Scintilla mag.	Aeromarine	1 Stromberg
Wright R-790	9 Radial	Air	515	30	—	—	45	220	1800	4.5″×5.5″	788	2 Scintilla mag.	Eclipse	1 Stromberg
Wright R-790A	9 Radial	Air	525	30	—	—	45	220	1800	4.5″×5.5″	788	2 Scintilla mag.	Eclipse	1 Stromberg
Wright R-1750 and R-1750A	9 Radial	Air	760	50 5/8	—	—	53 15/16	525	1900	6.0″×6.875″	1750	2 Scintilla mag.	Aeromarine	1 Stromberg

starter is not new in principle, but its application is comparatively new. The Aeromarine starter is used on large engines and the Eclipse on the smaller type. Both of these are efficient and operate satisfactorily on all types of naval aircraft engines.

Because of the fact that the inertia wheel is geared down to such a great extent, the starter can be made extremely small and light. The weight of a starter for installation on an engine weighing 800 pounds is approximately 25 pounds or more than 3 per cent of the engine weight. Small as it is, the device is capable of turning over the crankshaft at the rate of about 100 r.p.m. for a period of half a minute.

Starters may be energized in various ways. The most common method is that of the hand crank. In single-place planes where assisting personnel is not available, a small battery-driven electric motor is sometimes used for energizing purposes. Aboard aircraft carriers an electric external-cranking unit is employed, and one man can energize a large number of starters in a very short period of time.

Other types of starters, such as the gas-injection starter and the air-injection starter, are satisfactory but their disadvantages are so numerous as to probably prevent their general adoption in the naval service. The inertia type of starter is light, safe, and reliable. It is easy to maintain and rugged in construction.

Aircraft propellers. Before the first successful flight of the Wright brothers in 1903, various mathematicians speculated on the proposition that air propellers were analogous to marine propellers. There were two schools of thought at that time. One claimed that if proper corrections were made for the difference of density between air and water that marine practice in propeller design would apply equally well to air propellers. The other school of thought maintained that air being compressible, and having less density, and being subject to thermodynamic changes made it necessary that an entirely new theory of propeller design be produced. The air propeller first used by the Wright brothers in 1903 followed closely the marine theory but was modified to some extent to fit the then existing airfoil theory. It was made of a light frame covered with canvas.

From this humble beginning the air propellers of the succeeding years were made largely on the system of trial and error. They were made of hard woods of all kinds: were two-, three-, and four-bladed; solid and laminated; fabric covered, metal tipped or plain; of all diameters and shapes; of many types of blade sections.

No attempt can be made in this volume to describe the complete evolution of the present metal propellers, to describe the present various types, or to go into the aerodynamic principles involved in propeller design.

The propeller must fit the engine and plane and have as high an efficiency as can be attained; it must be safe and reliable against structural failures. The propeller in being rotated is subject to severe stress due to centrifugal force, upon which stress is superimposed, the bending moment due to the thrust which acts similar to a load on a cantilever beam. These two main stresses are further complicated in that there is a torsional stress in the blade due to the fact that the center of gravity of any one section and the center of pressure are not the same point. Other causes of stress in a propeller blade are bending moment due to torque and gyroscopic stresses.

Courtesy Douglas Company

DOUGLAS TORPEDO PLANE

In 1923 the first "Reed" slab-type propeller came into use. It was made of a slab of rolled aluminum alloy and then twisted to the desired pitch. This type was later changed, for reasons of strength, to the Reed R-type which somewhat resembles a wood propeller reproduced in metal.

Until about 1924 all aircraft propellers were of the fixed pitch type. That is, it was impossible except in a specially equipped shop to change the angles of the blade to fit new conditions of air speed or revolutions per minute. The detachable-blade type was a result of this restriction. This type consists of a steel hub into which are fitted the duralumin blades. The blades can be set on a plane table to any angle desired. Because of performance and cost this type has come into wide use in the Army, Navy, and commercial fields.

The advantages of the detachable blade type of propeller are numerous, and mainly that the same design of blade used in two and three blade combinations, together with small changes in diameter gives virtually several families of propellers. Experience shows that if a detachable blade is designed of uniform pitch but is set in the hub at a lower effective pitch the performance is bettered. In effect the lower setting gives a propeller non-uniform pitch, so it is a case of the pitch all along the blade fitting the actual air flow that exists. In this respect, non-uniform pitch blades, when used with the modern air-cooled engines give better results than uniform pitch blades. However, for best results the setting cannot be too far above or below the designed angle as in the extreme cases some sections would be working at either too high an angle of attack while at the other extreme some sections might have negative angles of attack. Further advantage can be taken of the adjustable pitch feature in that a better climb and take-off can be attained by reducing the setting about one or two degrees from normal.

Another advantage of the adjustable pitch type is that in an emergency due to shortage of propeller blades, the plane can be kept in the air by using a larger diameter blade, cutting it off to the correct diameter and setting it so as to give the required r.p.m. It is not maintained that this gives the best propeller possible but is often resorted to, to avoid keeping the plane in the hangar awaiting the arrival of the correct blade.

With the development in the last few years toward increasing engine horsepowers and speeds of rotation, it is imperative that propellers be made of metal and it is certain that gearing will become more necessary as this development continues.

Courtesy Bureau of Aeronautics, Navy Department.

CONSOLIDATED "NY" TRAINING PLANE

CHAPTER VI

AIRCRAFT INSTRUMENTS

The navigation of aircraft is similar to that of surface craft. In addition to the ordinary simple navigational instruments such as the parallel rulers and dividers, aerial navigation has necessitated the development of several new types of instruments to assist in piloting and to aid the navigator in determining position. Several of these, such as the inclinometer and the turn indicator, have no direct bearing on determining the position of the craft, but are required by the pilot to enable him to conduct his plane or airship efficiently on a desired course with unfavorable conditions, such as fog, clouds, and darkness. The majority of these instruments are mounted on the board in front of the pilot's seat.

Although instruments of one sort or another have been employed in balloons and airships for many years, their use in airplanes did not become general for several years after sustained heavier-than-air flight was an accepted fact. The chief concern of early designers was to produce a plane that was able to get into the air and back in safety, to the ground. With the solution of the primary problems of structural and power-plant design came an increase in the capabilities of the plane, and with it a demand for the primary power-plant and flight instruments. Further development of the airplane has made it still more independent of weather conditions until it has become a prideful slogan used by pilots in every sort of air activity—gypsy fliers, service squadrons, commercial air transport organizations—that their planes are in the air, completing their missions under weather conditions such that "even the birds are walking."

Extension of the airplane's sphere of capabilities has been accompanied and to some extent made possible by the development of the instrument equipment of the airplane. The pioneer pilots had few, if any, instrument aids. A tachometer, a bicycle rider's padded helmet, and a piece of yarn or ribbon secured to a strut, by means of which the pilot could make some estimate as to his flight path, represented all the visible piloting aids in some of the early planes—and often as not the helmet was left behind to reduce weight.

Even when instruments did become available, their installation and use in an airplane was frequently considered as a damaging admission of faint-heartedness or lack of piloting ability. The epithet of "instrument flyer" was one of scorn and derision. Nowadays, however, the ability to fly by instruments alone, the ability to bring a plane safely through conditions of fog, storm, or darkness—when the ordinary reference points of horizon, ground and sky are completely obscured—is recognized as piloting ability of the highest order. Perfection, or at least, broad experience in "blind" flying is an essential requirement for every service pilot. It is not improbable, as has been frequently pointed out in the aeronautical press, that some of the failures in long distance flight attempts were due to insufficient experience in blind flying rather than to failures of the airplane's structure or power plant.

The notes which follow will describe very briefly, typical airplane instrument equipment as installed in naval aircraft—service instruments as distinguished from experimental, test, or aerological instruments. Service instruments are those customarily installed for the purpose of supplying the crew of the aircraft with information necessary and essential for flight. They may be divided arbitrarily into the following classifications: power-plant instruments, flight instruments (which are those used for maintaining control of the airplane along the desired flight path), navigating instruments, and special equipment.

Power-Plant Instruments

The power-plant instrument equipment ordinarily consists of four instruments per engine; an oil pressure gauge, an oil temperature gauge, a fuel pressure gauge and a tachometer. For water-cooled power plants an additional temperature gauge for the cooling water is required, while for certain supercharged engines a gauge is provided showing the pressure being maintained in the supercharger, in terms of feet of altitude. Airplanes having a fuel system in which fuel flows to the carburetors by gravity (an arrangement characteristic of service flying boats) omit the fuel pressure gauge. The temperature gauges, calibrated in degrees centigrade, are of the Bourdon-tube type and measure the change in pressure caused by a change in temperature in a liquid or vapor-filled bulb and capillary-tube system, the bulb being inserted in the engine liquid, oil or water, temperature of which is to be determined. The tachometer, calibrated to read engine r.p.m., is of the centrifugal type, although both chronometric and electric tachometers are in use to a limited extent. Fuel-quantity gauges, which properly may be classed with power-plant instruments, as employed are of three chief types—the plain sight tube, the float type, and the hydrostatic type in which the air pressure necessary to force air out of a tube extending to the bottom of the tank is taken as a measure of the fuel content.

Flight Instruments

The flight instruments are those primarily used to assist in maintaining control of the airplane along a desired flight path. A group of instruments typical of those supplied to the service at the present time consist of magnetic compass, combined turn indicator and lateral inclinometer or bank indicator, air-speed indicator, and altimeter. Of these, the first three—compass, turn and bank indicator, and air-speed indicator or their equivalents—are absolutely essential for blind flying.

Magnetic compass. The magnetic compass consists of a very light-weight non-floating card from which two horizontal magnets are suspended, the axes of the magnets being parallel to the N-S line of the compass card. The card and magnet system pivots upon a hardened steel point turning in an agate cup, the pivot point forming part of the card system and pointing downwards as distinguished from marine practice where the cup is generally attached to the card. A retainer system, in which the card is fitted, insures that no matter how the compass is capsized the pivot point will always return to the agate cup. The compass is operative until heeled to an angle of about 20 degrees. The damping liquid is mineral spirits, a petroleum derivative. By the use of a light-weight mag-

a location fairly free from magnetic influences and severe vibration. Movable magnetic material, such as hoisting slings, guns, or controls, or a compass location that demands excessive compensation, will destroy the usefulness of this much maligned instrument. One air navigator of wide experience points out that there is the same tendency to blame poor navigation on the compass that there is for a poor golfer to blame his golf clubs. The magnetic compass should be used only as a direction indicator during straight flight. Whenever the turn indicator shows that a turn is being made, the compass indication should be disregarded until straight flight is resumed.

Earth inductance compass. Another form of magnetic direction indicator now available is the earth inductance compass. While not in widespread service use at present, it is considered to be very promising and an extension of its use in the future is probable, particularly in scouting and patrol planes. The best known form of earth inductance compass indicates direction in reference to magnetic north and consists of three major elements:

(a) Generator with driving equipment, the generator having no artificial field, but utilizing the lines of flux of the earth's magnetic field.

(b) Controller or brush-shifting and indicating gear by which the generator brushes may be set to give zero potential when the plane is on the desired heading.

(c) A steering indicator consisting of a zero-center galvanometer indicator, showing the electrical potential being produced by the generator.

With proper brush setting a required course is maintained by keeping the indicator reading zero. A 180-degree error in course is avoided by noting that on the proper heading the indicator will move in the same direction that the aircraft turns. One of the primary advantages of this compass is that a favorable location, magnetically, may be chosen for the generator unit, while the steering indicator may be installed in a position convenient for the pilot.

Turn indicator. The turn indicator at present supplied to the service, consists of a small air-driven gyroscope rotating about a horizontal athwartship axis, so mounted in a cradle as to be free to precess about a horizontal fore-and-aft axis when the airplane turns about its vertical axis. The torque developed by this precession deflects a spring, the magnitude of the deflection being indicated by a pointer on a dial. A dash-pot is linked to the precessional system to damp out excessive oscillations. Installed in the face of the instrument is a lateral inclinometer, the whole instrument being known as a turn and bank indicator. The turn indicator, or its equivalent, may be considered as one of the key instruments for blind flying. It does not replace the compass and a course steered by the turn indicator alone would probably be a curved path of wide radius. Nor does the use of a magnetic compass, which is dependable only in straight flight, obviate the necessity for a turn indicator. Three ways may be mentioned in which the turn indicator is of primary importance in blind flying. First, when endeavoring to fly a straight course it enables the pilot to detect a turning movement of the plane promptly enough to correct it before his compass begins a confusing erroneous swing or develops spinning tendencies due to a curved flight path. Next, when a turn is necessary, the use of the turn indicator and banking unit in connection with the air-speed meter, enables a correct turn to be made. Finally, should the plane get out of control, the turn indicator will greatly facilitate

netic system having a low moment of inertia and a low center of gravity, careful design of the pivot and retainer parts and the employment of an anti-vibration mount, a reasonably rugged and satisfactory compass results. Proper functioning in an airplane requires, in addition, that the compass be properly installed in recovery, by indicating in which direction the plane is turning. The particular value of the turn indicator in blind flying lies in the fundamental method by which a pilot maintains control of his plane, an item which has long engaged the attention of aviation medical authorities. The pilot orients himself primarily in response to three senses; first, the vision sense, second the deep-muscle sense, i.e. the so-called "seat sense" or "feel of the ship," and third the inner ear sense. Of these, the vision sense appears to be the most important. It has been well demonstrated that as long as a pilot can see even a single fixed point such as a faint horizon or a glimpse of the ground or a light showing through the fog, the three senses coördinate fairly well and flight with a reasonable degree of safety is possible. If, however, all vision outside the plane is blotted out, not only are the responses from the muscle sense and inner ear sense inadequate for orientation, but in addition the pilot's reactions may actually be entirely wrong and exactly opposite to the reactions he would have had if his vision sense had been operative. To supplement the pilot's senses the flight instruments have been given the most advantageous position possible on the instrument board. The preferred arrangement places the turn and bank indicator in front of the pilot, with the compass above, and the air-speed indicator, tachometer, and altimeter grouped closely around the turn indicator, so that the essential instruments may be observed with the minimum of effort and without distraction.

Air-speed indicator. The air-speed indicator in use at the present time is essentially a pressure gauge which indicates the difference between static pressure of the surrounding air and the velocity pressure, as developed by a pitot tube in the free air stream. Although the velocity pressure is proportional to the square of the speed, the indicating mechanism transforms this to a substantially linear scale, calibrated in knots. If connections are kept tight this instrument is rugged and reliable.

Altimeter. The service altimeter is a development of the aneroid barometer graduated in feet of altitude, the relation being in accordance with an arbitrary formula which defines a hypothetical atmosphere by a suitable altitude-temperature relation called the U. S. altimeter calibration standard. The chief weaknesses of this instrument as an altitude indicating device, aside from the mechanical defects which have been fairly well eliminated, are two; first, the fact that the barometer may change considerably while the plane is in the air; and second, the change in ground level in point-to-point. However, there is no instrument of comparable simplicity in sight as a replacement for the barometric altimeter.

MISCELLANEOUS

The line of demarkation between flight instruments and navigating instruments is not clearly drawn. Obviously, the compass, air speed indicator, and altimeter, and sometimes the tachometer, may be considered as navigating instruments. Of the instruments not yet considered, drift indicators and aircraft sextants are worthy of mention. The actual course of an aircraft over the surface

of the earth, called the track, is the resultant of the aircraft's speed through the air and heading, combined with the wind speed and direction. The drift angle is the angle between the heading of the aircraft and the track. One of the simplest form of drift sights consists of a device similar to a bearing plate. Drift is determined by picking up some object just flown over such as a house, road intersection, or other easily identified topographic feature and following it as far aft as possible, then reading the drift angle. For sea use, smoke bombs are employed, but skilled observers frequently obtain the drift by use of wave crests alone.

Although a number of inter-continental flights have been made without the use of astronomical observations, long-range over-seas service flying, particularly operations from carriers, will introduce navigational problems of the highest order and will necessitate the employment of every available navigational aid. Practically all forms of celo-navigation make use of the altitude of a celestial body above the horizon. While it is expected that the sea horizon will be used when opportunity permits, when the sea horizon is obscured or for night observations, an artificial horizon is necessary. There are three types of artificial horizons—liquid levels, pendulums and gyro-stabilized horizons of which only the first type appears practical at present. In the Davis-Radford octant, a double image of the bubble appears on a narrow strip in the center of the field, coincidence with the celestial body being made along a line formed by the intersection of the double bubble image. By the use of an astigmatizing lens the image of the heavenly body may be drawn out into a band or line long enough to span the central strip where the bubble images appear. In the improved Wilson bubble type, a virtual image of the bubble is formed at the focal plane of the telescope through which the heavenly body is being viewed. The bubble is formable and adjustable as to size, coincidence being made at the center of the bubble. Both instruments are suitable for use with artificial and natural horizons, day or night, and both are fitted with quick-reading micrometer-type verniers with endless tangent screws. Likewise, both are of domestic design and manufacture.

Bygrave slide rule. On account of the difficulties of solving long mathematical problems in an airplane the sights are solved on the Bygrave slide rule.

The accuracy with which planes can be navigated depends not only on such factors as expertness of the individual, completeness of preparation of necessary data, and the convenient arrangement and provision of the required facilities, but also on the conditions which may be encountered en route. Enforced radio silence may prohibit the use of the radio compass. Physical space available and uncomfortable surroundings must be taken into account as factors affecting accuracy of work.

The radio compass on board aircraft is similar to that on board surface craft. Its principal use is in scouting operations.

A course and distance indicator is furnished planes for the solution of graphic problems. It is a modified Battenberg course indicator.

The bearing plate is a simplified azimuth circle for use with the aero compass.

The aircraft pelorus is fundamentally the same as that used on board ship.

The recording barograph is a type of altimeter which automatically records the altitude as well as the time elapsed, thus furnishing a graphic record of the aircraft's flight.

The inclinometer is valuable as a means for checking the accuracy of the pilot's judgment in flying, and is particularly useful in the larger types of aircraft where the pilot's cabin is enclosed.

The instrument is of very simple construction, consisting of a curved glass tube partially filled with a mixture of alcohol and distilled water and usually colored to aid visibility. The glass tube is mounted in a suitable holder, the holder being marked with an angular scale.

When the machine is flying level, the bubble is in the center which is marked zero degrees. When a wing is lovered the bubble moves away from the low side. However, in a properly banked turn the bubble remains at the zero point. In this case the resultant of the gravitational and centrifugal forces remains perpendicular to the new position of the plane. Even in a very steeply banked turn, if properly made, the pilot feels no tendency to slip sideways toward the earth. He sits squarely and naturally in his seat. The bubble remains at zero for the same reason. Because of this fact a plane in a fog might be flying in a circle without the pilot suspecting it.

The fore-and-aft level consists simply of a glass triangular tube half filled with colored liquid. The triangle is installed in a vertical plane parallel to the line of flight. The pilot sees only the one leg of the triangle which is set flush with the instrument board. This side is graduated in degrees, zero being in the half way position when the plane is flying level, fore and aft. This level shows the pilot the degree of climbing angles of the plane under a given set of power or load conditions.

Unlike the air-speed meter the fore-and-aft level cannot be used to check the climb. The angle of climb varies with the speed and load. The greatest value of the instrument lies in its use on bombing, torpedo, and photographic planes where it is imperative that the craft be kept on a level keel.

In conclusion, it might not be amiss to point out some of the general considerations entailed in the production of service aircraft instruments. Although the physical forces by which they operate are, in general, small, thereby requiring the use of extremely light parts, they must be sturdy enough to withstand the shock of landings and take-offs and violent maneuvers. They must be highly damped to indicate correctly while undergoing severe vibration or while tilted at steep angles. As far as practicable they must be compensated for a wide range of temperature and density. Size and weight are matters of extreme importance. Every pound of weight not only adds its own weight to the plane but entails a corresponding increase in the structural weight of the plane, with its attendant penalty on performance. And finally, not only must the instruments be mechanically sound, accurate, rugged, and light in weight, but they must be suitable from the pilot's point of view, readily visible day or night, and furnish information to him at a glance, with a minimum of effort, without distractions and without making any appreciable demands on his time or attention.

California-Australia Flight

One of the most noteworthy aviation feats of late years was the flight from California to Australia of Captain Charles Kingsford-Smith, of Australia. The flight is of such interest in showing a triumph of aerial navigation that its details are here briefly given.

The Fokker monoplane arrived at its various destinations with express-train precision, despite the fact that stormy conditions were encountered on one leg of the 8,000-mile journey.

Three radio transmitting sets and three radio receivers were carried but the entire installation weighed only 73 pounds. The plane was never out of radio communication with surface craft, and several aircraft radio distance records were broken.

By communicating with surface craft in sight, the navigator was enabled several times to obtain the plane's "fix," and although such a method cannot strictly be called aerial navigation, it at least utilizes the superior ability of the surface craft to take observations.

In tabular form, the details of the flight follow:

Co-pilot, Charles T. P. Ulm, Australia.
Navigator, Lieutenant Harry W. Lyons, United States.
Radio operator, James Warner, United States.
Plane: Fokker monoplane, three Wright 200 h.p. engines.

Departed	*Date*	*Arrived*	*Mileage*	*Flying Time*
Oakland, Calif.	31 May, 1928	Wheeler Field, T.H.	2,400	27 hr. 28 min.
Hawaiian Islands	3 June, 1928	Suva, Fiji Islands	3,138*	34 hr. 33 min.
Suva, Fiji Islands	8 June, 1928	Brisbane, Australia	1,762	21 hr. 18 min.
Brisbane, Australia	10 June, 1928	Sydney, Australia	500	5 hr. 41 min.
Totals			7,800	89 hr. 0 min.
Average				87.64 mi. per hr.

* Longest unbroken flight over water up to time this volume goes to press.

Courtesy Bureau of Aeronautics, Navy Department.

AIR VIEW OF NAVAL AIR STATION, PENSACOLA, FLA.
Note the effect of wartime camouflage

CHAPTER VII

BASES, AFLOAT AND ASHORE

Bases for operation of aircraft are broadly divided into two classes, those on land and those on sea.

At the present time the Navy has a number of bases along the coast of the United States. In addition, at certain points in the various possessions, small bases are either located or strategical positions for bases are marked out.

Throughout the interior of the country the Army has flying fields at various army posts. The system of possible aircraft bases is completed by fields operated by aero clubs or by private individuals. In time of war those fields in the best positions will be taken for bases by the Aeronautical Board, and turned over either to the Army or Navy.

The present existent U. S. naval air stations are:

Lakehurst, N.J.	Lighter-than-air (LTA) base.
Anacostia, D.C.	Heavier-than-air (HTA). Experimental and operating
Hampton Roads, Va.	HTA and LTA. Fleet repair base. Operating reserve aviation training.
Pensacola, Fla.	HTA. Primary and advanced aviation training.
Coco Solo, C. Z.	HTA and LTA. Fleet repair base. Operating.
San Diego, Calif.	Same as Hampton Roads.
Pearl Harbor, T. H.	Same as Coco Solo.

U. S. Marine flying fields:

Quantico, Va.	Managua, Nicaragua.
Port-au-Prince, Haiti.	Hsin Ho, China.
Sumay, Guam.	San Diego, Calif.

U. S. Naval Reserve aviation bases (Operating and training):

Squantum, Mass.	Great Lakes, Ill.
Rockaway Beach, Long Island, N.Y	Sand Point, Wash.

U. S. Naval Reserve aviation bases (Operating only):

Minneapolis, Minn.	Oakland, Calif.
Long Beach, Calif.	Detroit, Mich.

Note: The above enumerated stations are subject to constant change.

In time of war the primary functions of air forces operating along the coast is to protect coastal sea communication by:

(1) Reconnaissance and patrol of coastal sea areas.
(2) Air escort for surface ships operating in coastal areas.
(3) Attack upon enemy craft (surface, sub-surface, or aircraft).

Bases Afloat

Aircraft, as an integral part of the fleet, must be prepared to move with it wherever it may go. Several means are available, and have at present been developed to a high extent.

(a) **Carriers**—Specially designed to carry and operate aircraft from flying decks; or to discharge aircraft from catapults and to permit them to fly on.

(b) **Tenders**—Seaplanes to be hoisted in and out. Types and numbers of seaplanes so carried will vary with the type of vessel, from specially designed tenders accommodating large numbers, to tugs or other small craft carrying but one. This type of operation requires seagoing, seaworthy airplanes of long radius, capable of keeping the sea and refueling in moderately rough weather. Such tenders may be fitted to hoist in only a few such seaplanes for emergency repairs, provided that seaplanes are developed having a sufficient degree of seaworthiness.

(c) **Other ships of the fleet** (Battleships, cruisers and such other ships as policy may dictate.)

When the fleet proceeds to sea, either to engage the enemy or to advance its base, there is space available on board for a definite amount of aircraft material, which represents a definite number of aircraft of the various types. As this material is used up there is no source at hand for replenishing the supply. Consider the advantage of a fleet that could be reënforced with aircraft in unlimited numbers, from its home coast. Perhaps this will be a determining factor in deciding the locality in which future sea battles are fought.

Carriers

Design

A carrier should have the following primary characteristics:

(a) High speed.

(b) Sufficient size to maintain high speed in heavy seas, without undue rolling and pitching.

(c) Unobstructed flight deck of sufficient size to afford adequate landing space, adequate parking space, and adequate launching space for at least three squadrons of planes.

(d) Adequate space for stowage and minor repair planes, and for berthing and messing of personnel.

(e) A method of disposal of exhaust gases from main power plant that will not interfere with operation of planes.

(f) Rapid elevators of sufficient size to handle largest type of plane contemplated for carrier operation.

(g) A secondary means of launching from hangar deck, either by forward runway or broadside catapults, is desirable.

The early ideas in regard to carriers tended toward a very large ship. The present tendency is toward a medium size, fulfilling above characteristics. The large size, such as the *Saratoga* class have several objectionable features. The cost of construction and maintenance is enormous; the handling in restricted waters

is difficult; the great length and deep draft limit their entry in many ports accessible to a medium class; a very large crew is required for operation; the high speed required means tremendous boiler power and almost insuperable difficulties in regard to any method of smoke disposal except through the vertical stacks with consequent obstruction of flight deck. Last, but most important to point out, this large carrier cannot, with present means employed or with any means in sight, land but one plane or launch but one plane at a time. Large size appears, therefore, to be of no advantage in speed of operation.

The present trend in design is toward a vessel of approximately half the displacement of the *Saratoga* class, of reasonably light draft, high speed, large beam, and unusual length for its displacement, with unobstructed flight deck, and with armor and armament, a secondary consideration.

Operation

The operation of aircraft from carriers is not as difficult as those inexperienced with such operations are inclined to believe. To substantiate the statement it is only necessary to point out that during a period of two and a half years, when the *Langley* had as one of its missions the qualifying of every naval aviator in the battle fleet as carrier pilots, the training was successfully completed without a single failure and not a single person was even injured during training. Toward the last of the training period, when methods had been thoroughly standardized it was found that the time required for the training on board, after preliminary training on shore, averaged only thirty minutes per pilot. This subject has been gone into in detail here merely to show that landing on board is not a "stunt," to be done only by special pilots under favorable conditions.

For operation of groups of planes from a carrier, the deck may be regarded as divided into three areas, the forward part of the flight deck being the take-off area, the middle part the parking area, and the after part the landing area.

Planes standing by for take-off are "spotted," i.e., secured to the deck in proper position in the take-off area, the arrangement on the deck depending upon the size of the planes and the number required in "ready" condition. They take off in succession, a sufficient interval being allowed between take-offs to avoid danger from slip stream of the plane ahead. The plane is released from the deck by a quick release devise, operated by the deck crew. While time intervals had best not be disclosed, it can be said that a large number of planes can be launched in a remarkably short space of time.

The parking area is the space in which planes landed are placed for servicing and made ready for another flight. Planes can if necessary be launched from the parking area after the take-off area is cleared.

The landing area contains the arresting gear, details of which cannot be disclosed. The general principle of the arresting gear is to provide means of checking the run of a plane after it has landed.

Operations with Fleet

The mission of carriers is to provide a mobile base for operation of aircraft with the fleet. This is a broader mission than it may at first appear. Therefore, the actual duties of a carrier may be very varied, and further development and

Copyright by General Electric Company. From a painting by Walter L. Greene.

U.S.S. "SARATOGA"

experience will undoubtedly increase the variety of duties under the general head of serving as a mobile base for operations.

At present, aircraft from carriers may be used for

(a) Torpedo attack
(b) Bombing attack—(1) high, (2) low or dive
(c) Machine-gun attack
(d) Smoke laying—(1) offensive, (2) defensive
(e) Scouting—(1) strategical, (2) tactical
(f) Spotting
(g) Offensive action against other aircraft.

In addition to basing planes for any or all of the above operations the carrier may be called upon to service aircraft launched from other carriers or other vessels, when such service cannot be performed by the vessel or vessels from which planes were launched. This applies particularly to the aircraft launched from vessels directly participating in the main engagement. It is obvious that a battleship cannot stop in the vicinity of enemy forces to pick up aircraft.

The "Saratoga" and the "Lexington"

The *Saratogo* and the *Lexington* are direct outgrowths of the Washington treaty. The treaty limits the total tonnage and the maximum tonnage of individual vessels in the case of all warships of a size greater than 10,000 tons. Aircraft carriers are the only warships in addition to capital ships, that are thus affected. The total tonnage of aircraft carriers allotted to the United States is 135,000 tons. The largest aircraft carrier that can be built under the treaty is of 27,000 tons displacement. There is, however, a clause in the treaty that provides that any nation can construct not more than two aircraft carriers of not more than 33,000 tons each, provided that the other restrictions of the treaty are not thereby violated. Provision is also made that tonnage that would otherwise be scrapped may for reasons of economy be utilized in the construction of these two special ships. The United States was the only nation to take advantage of these special provisions and the *Saratoga* and *Lexington* are the results. They are the largest, fastest and most powerful aircraft carriers that have ever been built, combining the characteristics of aircraft carriers with many of the features of large cruisers. The nearest foreign carriers in point of size to the *Saratoga* and *Lexington* are the Japanese *Kaga* and *Akagi* of about 27,000 tons each.

The two battle cruisers that would otherwise have been scrapped under the terms of the Washington treaty were converted into the *Lexington* and *Saratoga*. The use of these battle cruisers made it possible to provide under-water compartments that render the vessels unusually safe from under-water attack. Side armor gives a good degree of protection against other surface vessels and the aircraft carried on board are adequate for protection against air attack. Striking power against other surface vessels is given by eight 8-inch guns placed in four twin turrets. Additional striking power against both surface vessels and aircraft is provided by twelve 5-inch anti-aircraft guns that may also be used as broadsides. The anti-aircraft guns are arranged in groups of three with the maximum possible unobstructed arcs of fire.

In order to provide a deck upon which aircraft may be expeditiously operated, the "island" is offset to one side of the center line. The uppermost deck is continuous from stem to stern, being 888 feet long and 106 feet at its maximum beam. The interior of the ship is hollowed out to provide a hangar for operating aircraft. Elevators are used to transport planes between the hangar and the flying deck, cranes for handling aircraft are provided on the superstructure, and portable davits are located at convenient points. These carriers are capable of operating landplanes, amphibians, or seaplanes, as catapults are provided for launching the latter. In order to keep the flying deck as clear as possible most of the ships' boats are stowed in recesses in the sides.

The ships are made as self-contained as possible and consequently the usual facilities of air stations are provided. Shops equipped to overhaul and repair both metal and wooden aircraft and to overhaul and test all types of aircraft engines, are provided. Aerological equipment makes it possible to predict meteorological conditions, as well as can be done at any shore station, and the radio that is installed makes it not only possible to communicate with other vessels, shore stations, and aircraft, but also includes radio compass for directional control of aircraft. Two squadrons of heavy planes have been assigned to each vessel. These planes will combine the function of scouting, heavy bombing, and torpedo carrying. Two squadrons of the most modern fighting planes have been assigned to each vessel. The *Saratoga* has also twelve observation planes of the record-breaking Vought Corsair type, and the *Lexington* six observation planes of the same class. In addition, each ship is assigned a small utility unit for miscellaneous uses.

The total complement of each vessel calls for about 1,815 men and 219 officers. In addition to the purely aviation features, the usual requirements of first-class fighting ships are met in all respects.

Both the *Saratoga* and the *Lexington* were assigned to the battle fleet and joined that organization early in 1928. As soon as each vessel put to sea, aircraft operations were commenced. The first landing was made on board the *Lexington* by Lieutenant A. M. Pride, U. S. Navy, while the ship was on her way from the building yard at Quincy, Massachusetts, to the Boston Navy Yard. The first landing was made on board the *Saratoga* by Lieutenant Commander M. A. Mitscher, U. S. Navy, as soon as she had left the Philadelphia Navy Yard.

The *Saratoga* was built by the American Brown Boveri Company, Camden, N.J., and the *Lexington* by the Bethlehem Shipbuilding Corporation, Quincy, Mass.

Tenders

Lacking the necessary carriers, naval aircraft on duty with the fleet can depend upon support only in protected harbors or in a favorable sea.

Long range seaplanes are required to operate with tenders. A rendezvous is assigned. The planes alight alongside the tender, are refueled, and necessary repairs made. The crews of the seaplanes have quarters on board the tender. The planes themselves may be hoisted aboard for repairs.

To test the practicability of this arrangement a fueling test was made in the summer of 1924. A *DT-2* (torpedo) plane refueled from a destroyer at sea. The

fuel was transferred by means of a hose. An idea of the condition of the sea may be obtained from the fact that during the operation the destroyer was rolling about 20 degrees. After refueling the plane resumed flight unassisted. The success of this venture must not, however, give the impression that fueling at sea has an unlimited application.

The tender may in isolated cases be called upon to fuel her planes in the open sea, but only in rare cases. The tender is designed to base her planes in the same manner that a mother ship bases her submarines—under the shelter of land. In the Pacific many coral reefs are available and serve as well as land.

The apparent disadvantage of operating seaplanes in this manner is reduced, when it is recalled that the great naval battles of history have been fought almost within sight of land.

On Other Ships of the Fleet

A third means of carrying planes with the fleet has been developed. Planes are carried on board ships of the fleet according to the current policy. This involves the problem of launching. The first solution took the form of the runway on top of the turrets, the plane taking off under its own power. This has been replaced by the turntable catapult, which has been in course of evolution since 1915, and has been developed to the form now adopted for general service on all battleships in the fleet. The immediate problem in catapult design is the development of an installation capable of launching, at the necessary flying speed, machines of at least 6,000 pounds weight. Battleship installations, in which the projection is accomplished by compressed air charges, are capable of handling weights up to approximately 3,000 pounds and insure adequate flying speed for machines at the end of a 60-foot run. The substitution of powder charges for compressed air, with provision made for a slightly longer run, provides means for launching satisfactorily all types of planes which can be carried on board ships.

A modification of the turntable catapult will most likely be effected by placing a fixed catapult on top of the high turrets.

Once properly installed the actual launching is not difficult. It is upon the return of the plane that difficulty is encountered. The plane lands in the water alongside the vessel and is hoisted on board. The hoisting of aircraft into their places is an uncertain task under most favorable conditions. For this reason it is essential that Navy personnel understand approaching, towing, and hoisting of seaplanes.

In approaching a seaplane in a boat it must be borne in mind that the plane is more difficult to handle than the boat. Although the same rules of the road apply to both craft, the general prudential rule should govern the action of the boat. Should the boat desire to go alongside the seaplane it should establish communication with the crew of the plane and their directions, if given, should be obeyed. The approach should be made slowly from ahead. Aircraft with engines stopped drift rapidly to leeward but remain head into the wind. An approach from astern even in a light breeze might precipitate a very disagreeable tangle. In case of doubt the boat should back away and make another approach.

The towing of a seaplane under any but very favorable conditions is a delicate undertaking. The following notes apply to any type of boat or vessel:

The pilot of the plane, as soon after landing as practicable, rigs a sea anchor to reduce his rate of drift. If the seas and wind are high the vessel should steam slowly across the stern of the plane, trailing a long tow line and creating an oil slick if necessary. The line can be readily picked up as the plane drifts over it. This method, in point of time and safety, is the most satisfactory that can be employed in the majority of cases.

If the towing of an aircraft is necessary for any great length of time, or under unfavorable conditions of wind and sea, the gear with which aircraft are ordinarily equipped will not suffice. The towing cleats provided on pontoon types and the towing pendant on boat types will not stand up under the strain. On all types a bridle should be rove off with line sufficiently heavy to withstand the strain and the tow line secured to this. For *PN* type a 3-inch manila line is the right size for the bridle. On the pontoon types the bridle should be rove off about the forward pontoon struts. On the boat types the bridle should be rove off about the engine struts. In both cases the tow line should be secured to the bridle forward of the bows. On all types, wing lines should also be rove off to reduce yawing as much as possible.

A stern drag consisting of a sea anchor or buckets should be rigged, with its drag line leading through the hand grips on the tail, or through the stabilizer braces. All movable weights should be moved aft and it may be necessary on large planes for members of the crew to ride on top of the horizontal stabilizers.

Towing up wind is the simplest situation encountered in towing. In spite of the wind from ahead, the plane will yaw considerably unless the weight is concentrated aft and a tail drag rigged. The speed of towing will depend upon the sea.

In towing cross wind greater difficulty will be experienced because of the weather cocking tendency of the plane. To offset this a heavy tail drag and perhaps a drag from the lee wing will be required. A windward wing line to the towing vessel will also be of help. If the wind is moderate in velocity, it might be advisable to ride one man on the windward wing to prevent the wind from getting under it and thereby burying the lee wing tip. This tendency marks the initial step in capsizing. The speed of "tip towing" varies with the velocity of the wind and the state of the sea. Great care must be exercised by the towing vessel under any but calm-weather conditions, and a man should be stationed at the stern (if a large ship) to relay messages from the plane to the officer of the deck.

Towing down wind should never be attempted under any but ideal conditions of wind and sea. The plane will attempt to override the towing vessel and will yaw excessively. With light winds it can be accomplished with heavy tail drags.

If the seas are heavy and the wind is strong, far better results can be obtained by allowing the plane to make leeway, headed directly into the wind. A light sea anchor may be rigged from the bow to keep it from falling off wind. The bow cockpit cover should be secured and if the seas are breaking an oil bag should be used. The weight must be placed well aft, and it is well to have one or two members of the crew in a position so they can quickly move to one wing or the other.

For hoisting aboard, seaplanes are provided with slings. These should always be used if possible. If slings are not available then lines should be rove

off to balance the plane in approximately the same position as do the slings. These should be attached to heavy fittings on the plane such as engine bearers or passed completely around the fuselage, using spreaders to prevent crushing. If the engine of the aircraft is running the plane should be slowly taxied up wind toward the vessel and the engine cut in plenty of time to prevent damage to the plane by ramming the ship. A heaving line should be cast to the aircraft as soon as the propeller stops, and the plane secured by that while wing lines are being secured. After wing lines are secured, the slings should be passed over the hoisting hook and the personnel in the plane should signal the ship when ready to hoist. All slack should be kept out of the wing lines when hoisting to keep the plane from swinging.

In case the plane's engine cannot be used the plane must be towed up wind to a position for hoisting.

In any event, as the plane nears the ship, personnel should be placed in such a position along the side of the ship as to prevent the airplane striking it. It is very easy for a pilot to overrun in approaching. This is considered by pilots a very important point.

Maintaining Flight During Battle

Proper handling will often save a disabled seaplane but this procedure has little application in time of battle.

A solution of the problem of maintaining planes in the air during battle is being worked out. It is not intended to attempt salvage for disabled aircraft until after the battle. This same policy has always been pursued in regard to surface craft. Planes launched from catapults in war time will be of two types—amphibian planes and landplanes. Those launched from carriers will be landplanes. All of these can, upon exhaustion, land upon a carrier to replenish necessities of flight. In case of a forced landing the amphibian can land on the water and float in a moderate sea. The fighter, having only wheels, is not so fortunate if forced down.

All of our wheel-equipped planes carry flotation gear which should keep them afloat several hours, unless the plane is so badly crashed in the water landing that the flotation gear is made inoperative.

A practical method of fueling in the air has been developed, but the arrangement for maintaining planes in the air outlined above seems, just now, to be the most effective.

A plane forced down might have enough altitude to glide and alight in the water near some friendly disengaged vessel and trust to luck that time could be spared for rescue. Only in rare cases could vessels be expected to take time to hoist the plane aboard.

Planes launched from the turret platforms of the Grand Fleet in the North Sea faced a different problem. They had the disadvantage of being landplanes with no carriers to land upon for fuel. Some made their way back to Scotland; others were not so favored.

A provision for the rescue of stranded pilots is certainly worth considering from a standpoint of morale alone.

Courtesy Bureau of Aeronautics, Navy Department.

A Recent Type of Patrol Plane
The *XPN-12,* equipped with Wright Cyclone Motors.

CHAPTER VIII

SCOUTING

The aircraft is of great importance to the fleet in scouting operations. Valuable as it is, however, it can only be considered as an auxiliary since aircraft scouting, at sea with the fleet, is always conducted from, and directed by, surface craft. Aircraft cannot yet be used for all types of scouting principally because they are not self-sustaining. At the present time it seems that their usefulness is limited to the following:

1. Search.
   (a) Out and in.
   (b) Station patrol.
   (c) Retiring search (assisting surface scout).
2. Protective screening.[1]
3. Contact scouting.

This does not take into consideration the airship. Airships can be deployed for search in the same manner as can surface craft and there are occasions on which the airship would be of inestimable value as a scout. The advantage of having a scout capable of ranging about over the sea with the fleet and ready, when needed, to proceed in search of information is, of course, a very great one. Even in the face of adverse weather conditions the airship is not hindered to a great extent.

There are, however, several characteristics beside range, speed, and endurance to be considered before the airship can be fully accepted for scouting missions. The greatest weakness of the airship is its vulnerability to attack. The substitution of helium for hydrogen as a lifting agency, reduced in a large measure, its vulnerability to anti-aircraft fire and combat-plane attack. But the bulky dimensions and relatively poor maneuverability inherent in all airships continuously invite aggressive pursuit which, if continued with determination, might result in their being driven from station or destroyed.

On the whole the future usefulness of the airship to the fleet depends to a great extent upon the means provided for defending itself against hostile airplanes. It undoubtedly would be of service in overseas reconnaissance. The extension of this service is furthered by using helium, by providing an efficient defense by means of machine guns, and by means of fighting planes suspended underneath or carried on its back. Just at the present the particular sphere of the airship appears to be in a strategical rather than a tactical field.

[1] Screening is not, correctly speaking, included under scouting but it will be discussed here because of its close association with scouting so far as aircraft are concerned.

OVERSEAS SCOUTING

Overseas scouting by planes is affected—(1) by the radius of action of the aircraft; (2) by the ability to navigate; and (3) by morale.

The duty of scouting demands of the pilot an unusual determination to adhere to his mission. It is obvious that on a long, tedious flight where the objective is vague, the temptation to attack a stray enemy plane here or there, or to "zoom" a friendly surface craft, will be a real temptation, and must be withstood lest the pilot fail in his objective. Higher morale is demanded because of the additional factor of *loneliness*. To fly several hours over a sea entirely innocent of surface craft from horizon to horizon engenders lamentably the kindred emotions of doubt and loneliness. Again the pilot must not be diverted from his objective. The assurance of an enemy's absence from a sea area is invaluable to the commander in chief.

As planes become more seaworthy and self-sustaining the less the risk involved in long flights over the sea. There is a question as to the amount of improvement possible on planes that can be carried on board ships. There is at present a definite limit to the size of such planes, and size has a very direct bearing upon seaworthiness.

The pilot starting out on a scouting flight has a given area to cover, as well as a return flight to his ship. The fuel supply definitely limits the time of his flight and the weather conditions influence the actual distance covered. The necessity of bucking a head wind on the return trip, for example, would materially diminish the possibility of thoroughly covering the area. If he should be forced to land during the flight, his plane could survive only under favorable conditions of sea and weather. Even so, unless assistance is near, what is the answer? The opinion has been advanced that overseas scouting, on a large scale from a ship, can be carried on, but that the risk is too great to permit its practice in peace time. Perhaps this is so, but we cannot expect to be proficient during war in those things which we fail to practice in time of peace.

It must be borne in mind that scouting with airplanes is largely in the nature of a defensive operation. Scouting planes in their present stage of perfection cannot take offensive action against the enemy scouts unless in large numbers. This condition is extremely unlikely in a scouting operation. The scout's greatest asset, next to high speed, is its increased vision, yet this increase of vision is dependent on the weather. The weather is sufficiently clear on our Atlantic Coast to enable a plane to see farther than a ship only about 40 per cent of the time. Also planes will probably find it difficult to track an enemy throughout the hours of darkness.

In regard to night flying the following is quoted from an address by Captain W. R. Gherardi, U.S. Navy, before the War College, August, 1923:

Night flying is now before the public eye by reason of the fine performance of the air mail service in spanning the continent in twenty-eight hours. The glowing accounts of the success of this venture are apt to be misleading to one thinking in military terms. I shall quote the opening paragraph of a conservative editorial appearing in the New York *Tribune* within the past two weeks:

"The successful night flying by the planes carrying the coast-to-coast air mail gives assurance that a regular transcontinental service can be maintained. The flight through the dark hours, with powerful beacon lights at 25-mile intervals and minor beacons in between to guide,

was the critical part of the experiment. The pilots fully met the test. The chief delays were in the daylight sections of the route, owing to bad weather."

Note these two points—first, the planes were guided through the night by powerful beacons at 25-mile intervals with minor lights in between, and second, that the chief delays were owing to bad weather.

In addition to these points it is to be remembered that the pilots continually fly over the same route year in and year out. They get to know every angle of the landscape and to know every possible landing area along the way, and last but not least they have but one function—to fly.

The naval night-flying problem is not so easily solved. In the first place, man's visual sense is the most important in determining position in space and maintaining balance in that medium. Therefore, with the present lack of suitable instrument installation, it is necessary that the average pilot have some fixed mark or light in order to permit orientation. On the darkest night over land the pilot can dimly perceive the horizon, unless of course in clouds. Over the sea no such condition obtains. What little light there may be is refracted rather than reflected and the anxious flyer has the sensation of being in an ink bottle. This becomes even worse in clouds, for the air currents add to his troubles.

In the course of a night scouting flight, ten or more hours in duration, varying conditions of weather will be encountered and if aircraft are to reach a level of military dependency, the physical failures of the human being must be reckoned with and given serious consideration.

To obtain a true estimate of the value of aircraft for tracking or other scouting at night, it would be advisable to carry out experiments along these lines. The value of planes for this purpose would be greatly augmented with the invention of an adequate engine muffler and I understand such a devise is not far in the future owing to the use of a new valve metal that does not warp when overheated.

Night flying will play a very important part in future warfare and the Navy is training all aviators in this phase of aviation before they are officially designated as pilots. Night bombing with the aid of 500,000 candle-power parachute flares would render anti-aircraft defense rather difficult. The parachute effectively sheds the light in all directions but above. Firing at planes above such flares would be like aiming at an object behind the sun at noon. This is but one means of using aircraft at night but it will bear grave consideration.

Search

The surface scout can cover only a very definite area in a given time. The same scout carrying an airplane has its capabilities greatly increased. Operating with the airplane it can cover a greater area, or, if circumstances permit, it can cover the same area at greatly reduced speed with consequent reduction in fuel consumption. Where there are several scouts operating together the increased area covered has the effect of increasing the front.

The practical use of a plane operating from a scout entails some problems which not only render the arrangement difficult but reduce the apparent advantages. The scout running a retiring search curve will probably require the plane to make a flight at dawn and one before dusk. The plane is launched by a catapult. Upon its return the scout must stop. The plane lands in the water and is hoisted aboard into place. Aside from the possible damage to the plane the operation may easily require half an hour, a considerable discount on the advantage gained. Success in getting the plane on board depends greatly, in any case, upon the weather. With the carrier this difficulty is eliminated.

Screening

The air scout becomes of greater value when there is an urgent need of definite information concerning a certain area. The advantage gained by the use of a

flight of planes to cover it is apparent. Screening may be considered as an extension of this service.

When approaching hostile waters it is highly desirable that the commander in chief of a force at sea be informed as to the probable enemy forces in an area covered by a night or day run from his force. By means of a protective screen, using planes from the carriers accompanying the fleet, positive or negative information concerning these enemy forces can be obtained. An operation of this sort requires a relatively large number of planes because the extent of the search must be almost a complete circle.

Contact Scouting

The air scout will likely reach its greatest usefulness upon sighting a strange vessel or smoke. The plane takes the air, returns, and is taken aboard, having obtained a description and possibly the identity of the stranger.

The first evidence of cantact with the enemy screen will probably be a series of contacts by the scouting force. Planes taking the air under these conditions are in a position to obtain information of great value. It is of first importance that the commander in chief know the strength of the enemy force and its disposition. Upon the information furnished by the planes he will most likely base his orders dispatching ships for the destruction of this enemy force. Information given by the air scout of the presence of the enemy's main body, and his report of its disposition, will influence to a considerable extent the manner of concentration as well as the deployment for the opening of the engagement.[1]

[1] For more detailed information concerning employment of aircraft in scouting see "Service of Information and Security."

Courtesy Bureau of Aeronautics, Navy Department.

COMING ABOARD

CHAPTER IX

AIRCRAFT ACTION AFTER CONTACT

After contact, aircraft activity develops rapidly. Strategical scouting merges into tactical scouting and the demand for accurate information becomes urgent.

This increase in aerial activity influences the position in the fleet occupied by the carriers. The bombing, torpedo, and fighting planes are supplied by these ships. The probable immediate needs for aircraft demands that the carriers be in a position to place their aircraft at the disposal of the commander in chief without delay. Aside from this consideration the additional protection afforded against underwater attack logically places the carrier in the vicinity of the battleship divisions.

In sea engagements of the future concerted efforts will be made by the enemy to draw aircraft into the air. Each time air forces are launched there results a certain wastage. An enemy doubtless will attempt, by small demonstrations, to cause premature use of air forces.

It is improbable that aerial reconnaissance on either side can be prevented. Visibility is so good from the air and a single plane so difficult to detect at a distance that both contestants will surely have the benefit of continuous reports. It seems wise to accept this condition as a matter of fact and conserve forces. The reconnaissance planes will have made their reports before discovery and it is certainly of more importance that an attempt be made to obtain absolute control of the air immediately before the main engagement.

Command of the air for a limited period over any particular area may not be difficult to obtain, if a determined effort is made, but the retention of this command, when it is strongly disputed, is another thing. The real command of the air refers to that condition which permits detached groups of aircraft to perform their missions without danger of attack.

As two opposing fleets come within striking distance, the question of when, what, and with what to strike will be of great concern to the air commander. It is presumed that how to strike will have been previously determined by the development of air tactics. The force that first seriously damages the major source of aircraft supply of its opponent will gain a material advantage and this advantage becomes the more vital the greater the percentage of aircraft on board at the time the carrier is damaged. It would seem, therefore, that the time to strike is at the earliest moment that aircraft can reach the enemy's carriers and successfully carry through their offensive. But to determine when this time arrives is the difficulty. A start made too early may not succeed on account of failure to make contact or loss of the support of fighting planes due to their limited endurance. Accurate and properly applied information is most necessary in selecting the proper time to strike. Consider the situation when an action is impending. A commander who launches his planes too early will lose their support and coöperation from exhaustion of fuel supply, and on the other hand he who launches them too late may give command to the enemy with the resultant initial

advantage. Again a commander who, by unwise use of his aircraft, has so depleted his force, either by actual loss of planes or by lowering the morale, has at once ceded an advantage to the enemy.

It is sometimes stated that the defense against aircraft is aircraft, but this should not be taken too literally when planning a campaign in the air. An aircraft is primarily an offensive weapon. It has the period of its endurance in which to accomplish its mission. If it fails to take advantage of any and every opportunity to do all the damage within its power, during this short life, it will have failed in its maximum accomplishment.

The value of aircraft acting on the defensive as a protective group against enemy aircraft is doubtful, unless it is in connection with an offensive move. An air force cannot hope to prevent an air attack by the mere placing of aircraft in certain protective screens or by patrolling various areas. There is no certainty, even with preponderance in numbers, of making contact with enemy aircraft before they have delivered their attack, and there is no certainty if contact is made, of being able to prevent the attack. It seems, therefore, that the most effective defense against air attack is offensive action against the source, that is, the enemy aircraft carriers. The weapon of this offensive will probably be the bomb. Light bombs can damage the upper deck of a carrier to such an extent that aircraft operations can be either definitely prevented or seriously hampered.

Whether for attack upon carriers or for the carrying out of subsequent missions, it seems probable that once aircraft have been launched at the beginning of an engagement their movements will be governed principally by doctrine. Before planes take the air they will no doubt have been assigned definite positions in flights that have been practiced in operating as units, and they will be familiar with the tactics that are to be employed in carrying out their assigned missions. Each flight, acting under a leader, proceeds towards its objective alone or in combination with other flights. Thus we conceive the various types of aircraft assembled in flight and combinations of flights, each flight familiar with its assigned mission and cognizant of its probable objective. When such a flight or group of flights starts out for its objective in accordance with its previously assigned tasks, it cannot well be effectively diverted to some other objective by a commander on the surface unless the new objective is in accord with an understood doctrine. It is also very doubtful if a commander on the surface, after the air battle is in full swing, would consider himself sufficiently well informed of the situation to issue any orders to units in the air. It is difficult to conceive of the possible mêlée that might exist in the air during a naval battle, and unless the air forces, from the very start, act in accordance with doctrines and proceed to their objectives in accordance with assigned missions, disorder and disorganization may soon result.

When two fleets are engaged aircraft will undoubtedly be used for their primary purpose, that of gaining command of the air and using that command to damage the enemy. Having once gained command of the air it is then practicable for aircraft to assist in the main battle line, by such tactics as are applicable.

Courtesy Curtiss Aeroplane and Motor Co., Inc., Garden City, N.Y.

A Curtiss-Navy Shipboard Fighter "Sea Hawk" (F7c-1), Pratt and Whitney "Wasp" Engine

CHAPTER X

COMBAT

Combat aviation within our fleets is that class of our air forces whose mission it is to attack and defeat hostile aircraft in flight; whose primary mission in other words is to establish and maintain aerial supremacy for our fleets both before and during a fleet action. Secondary missions may also be assigned our combat squadrons or various parts of them; such missions as strafing with machine guns or light bombs the tops and upper works of light craft, the torpedo-tube crews of destroyers at the instant of attack, protection of our own spotting planes, etc.

It is, of course, manifest that the accomplishment of all secondary missions of the combat forces, as well as the primary missions of other air forces, depends directly upon the successful prosecution of combat's primary mission. It may, therefore, be concluded that our combat squadrons constitute the backbone of naval aviation, and it follows that the success of our fleet in action depends upon the success of our combat squadrons.

Nations can improve their aeronautical strategic condition by planning and building. By experimenting, and testing design and by the introduction of new materials into construction, the quality of the individual machines can be constantly bettered. For aerial combat tactics, however, to keep pace with aeronautical strategy and aircraft design in peace times, is a far more difficult problem. It is with the solution of this problem that the fleet combat squadrons are directly charged. Since the close of the World War, they have striven constantly to improve their fighting methods, and those officers who have made a study of the problem believe they have succeeded in so doing. They must succeed, for it is highly probable that the next fleet engagement will be preceded by a tremendous aerial battle. *We cannot wait until that time comes* to learn the best combat tactics possible with our material.

It is true that the methods we develop in peace times cannot be proved under fire until hostilities come. But, by the use of camera guns and towed-sleeve gunnery practices, we can approximate war conditions fairly closely, and in addition we can make sure that our tactics are in accordance with the fundamental principles of war.

The airplane was first recognized as a weapon during the World War and it was during this war that as such it was mainly developed. It was used in many ways and failed as an effective weapon in several ways. Each failure was caused by a violation of one or more fundamental principles of fighting and not because of any intrinsic deficiency of the airplane as a war weapon. It is unreasonable to suppose, without adequate proof, that the point of development of airplane tactics at the time of the Armistice was the utmost development possible. It is as unreasonable to suppose that we cannot in peace time continue development from that point, despite the natural handicaps.

All tactics in the air, on land or on water, and of fighting with whatever weapons, to be successful must be in accord with the several basic principles of war, which may be thus enumerated:

(1) The principle of superiority.
(2) The principle of concentration.
(3) The principle of the offensive.
(4) The principle of the tactical advantage.
(5) The principle of surprise.
(6) The principle of the objective.
(7) The principle of initiative.

It is only by the effective application of these principles that individual combat, wide-spread battles, or whole wars are won. Defeat is a direct result of their violation. No one of them may be called more or less important than the others, although the conditions of each situation demand the greater use of one or more of them. These principles must be kept constantly in mind throughout the study of present fighting tactics, the use of combat aviation in the World War, and in deciding upon the best tactics for future use.

It is the purpose of this book to lay stress upon the *fundamental principles of aerial combat* and not upon the detailed instructions or policy relative to the attack by planes of one type upon planes of the same or other types. The combat pilot during the course of his flying instruction will learn the practical application of the underlying principles.

It is interesting and instructive as well to study the methods of the individual World War "aces," although it is highly probable that the day of the individual ace has definitely passed.

It has been stated by some authorities that several planes during the early part of the war were brought down by well-directed rocks. In fact, such an instance was officially recorded in 1914 by the German general staff.

On August 14, 1914, it was recorded that an indecisive duel occurred between a Frenchman and a German, in which the Frenchman used a Browning pistol. Another report on August 28, 1914, is as follows:

> An English pilot, emerging from a cloud, found immediately beneath him a German airplane. Swooping down to within revolver shot he emptied all his chambers with an effect he could not observe because the cloud once more enveloped him. Later on when he emerged from the cloud he saw underneath a small crowd gathering around a smashed airplane, and he came to the conclusion that his revolver shots had not been without effect.

These early combats were incidental to the other work required of the air units. It was not until great improvements were made in the designs and construction of single-seated airplanes, machine-gun mountings, and synchronizing gears, that combat in the air became an important factor and the necessity for organizing combat aviation as a separate class of the air forces was appreciated.

After machine guns were mounted on airplanes the first combats were carried out by pilots working alone, relying upon their individual skill to trap the unwary opponent. The success of these early aces can be attributed largely to their youth and aggressivenss. Their methods were simple in theory, but difficult of execution, as the later inexperienced pilots found out. The real point is that

such men as Ball, Guynemer, Boelke, and all the others instinctively applied fundamental principles of fighting which upon little study reveal themselves as the principles of war above noted.

The most important single factor in combat is the range at which fire is opened. The natural tendency in all forms of aerial combat is to begin firing at ineffectively long ranges. Experience proves that the most effective range for firing in pursuit combat is well under 100 yards, the individuals having the greatest success usually opened fire at 150 feet or less. Notwithstanding the development of airplanes of much greater speed and guns of large caliber, it is probable that the present effective ranges will not be appreciably lengthened for close-maneuver combat. In fact, a tremendous increase in the range of guns and the speed of the fighting airplane beyond other types of aircraft may tend to develop less accuracy in firing.

Surprise has always been one of the most potent factors of success in war. Surprise in its primary sense is largely a matter of alertness. Surprise in its secondary sense is dependent upon the adeptness of the attacking pilot. A pilot who is thoroughly at home in the air can effect surprise by unexpected execution of an abrupt maneuver even in view of, and close upon the enemy. A maneuver of this sort may leave the enemy in doubt as to the intention, and to place the attacker in a blind sector before defensive measures can be taken.

Secondary surprise is dependent upon power to maneuver. It is only utilization of the plane's full performance. High fighting plane performance is essential. Great power-of-maneuver is a weapon placed in the hands of the pilot, the proper use of which will make possible greater opportunities for secondary surprise. It is here that the mechanical flyer fails utterly. The instrument board makes no contribution to the accuracy of the evolutions of a fighting plane engaged with the enemy. The pilot fighting toward success knows to the last ounce the demands to be safely made on his engine, and to the last fraction of a degree how steeply his plane can be climbed. He has no secret system of obtaining his knowledge. He simply knows. It is the result of aerial fitness and of assiduous self-training. He has acquired what is called, for want of a better word, the "feel." Fighting planes in mimic combat over the flying field give daily proof that this quality of "feel" is no phantom. One of two evenly matched planes engaged in combat will out-perform the other. One pilot makes more intensive utilization of his weapon, and so conveys the impression of being better armed. He is better armed only because of his ability more thoroughly to employ the power of maneuver that lies at his command.

The fixed gun on the two-place plane is its primary weapon. It is served by the pilot, with whom the initiative rests, and who follows fighting plane fire tactics. The flexible gun operated by spotter, observer, or gunner, is a secondary weapon.

The zones of fire differ with the types of airplanes. The flexible gun, being designed for the protection of the rear, can be brought to bear in all overhead zones, through 180 degrees aft from wing tip to tip. It covers the sectors under the lower wings and the tail, and forward in overhead zones, with a degree of completeness depending upon plane design and flexible gun installation. The most vulnerable sector is the blind one under the tail. The two-place plane may mount a tunnel gun firing aft and down through a tunnel in the fuselage and

covering only that sector aft under the tail which is beyond the fire zone of the flexible gun.

A skillfully flown fighter can reach a position a hundred yards behind and fifty feet below the tail of the two-place plane and effect complete surprise. The fighter is then in a position to deliver effective fire with minimum exposure to the fire of the flexible gun. Having failed in effecting surprise, or having opened fire, the attacking fighter utilizes its superior speed and greater power of maneuver to avoid the enemy fire. The two-seater will make a sharp turn in an effort to uncover the attacker and bring the flexible gun to bear. Skill on the part of the attacking pilot will neutralize the attempts of the enemy to bring the fighter within a zone of fire. The fighter, superior in speed, meets each sharp turn of the two-seater by following its tail.

The attack of the fighter may then be driven in from a flank as the hostile two-seater turns. Rapid change of position by the fighter from one flank to the other, accompanied by short bursts of fire, will distress the observer, and confuse the pilot, who may be led to violent changes of direction. The rapid shifting of the fighter from one side of the fuselage to the other may result in indecision by the observer as to which side to train the flexible gun and the violent movement of the two-seater destroys its steadiness as a gun platform. These two factors combine to render accurate or rapid fire from the flexible gun very difficult.

There is a foreign school of aerial tactics which holds the flexible gun to be the primary weapon of the two-place plane. The acceptance of this doctrine requires that the plane always be maneuvered to develop the fire of the flexible gun, all fire by fixed guns being restricted to secondary opportunities which are more the result of chance than of creative effort by the pilot. This procedure certainly has its place in the tactics of the two-place plane, but to prescribe it as the basis of two-seater tactics, is to erase the pilot's initiative, and limit the fire development of the plane to an almost purely defensive gunfire. The most vigorous attack, in which the gunfire of the plane is brought to maximum effectiveness, is that made by the pilot in the manner of a fighting plane, and immediately followed up by the pilot steadying the plane and momentarily holding position for the observer to deliver an offensive fire with the flexible gun.

The two-seater attacked from behind and below makes an abrupt turn timed to uncover the attacker at a moment when he is within range and confident of a complete surprise. The element of surprise may be reversed, and the attacker beaten off by a hot burst from the flexible gun. Isolated attacks from above and behind the two-place plane offer only target practice for the flexible gun.

A dangerous attacker with whom the observer must cope is the plane which dives vertically upon him. Accurate gunfire from the flexible gun against this attacker is rendered difficult by the position of the flexible gun when it is brought to bear.

The mission of the two-place plane, other than the two-place fighter, demands that fighting be avoided. The two-seater usually opens fire at extreme range, and may be expected to assume the offensive when attacked. But the fighting tactics of the two-seater, however vigorous they may be, will usually be with the objective of getting clear and not of seeking to prolong the engagement. The

proper employment of the two-place observation plane, and torpedo plane, does not permit their conducting offensive fighting patrols.

Fighters making head-on approaches must avoid overrunning the two-seater or diving past it. To avoid overrunning a turn must be started long before the fighter is upon the hostile plane, and completed before it reaches a position directly over. If the turn is started too late it will not be completed until the fighter is several hundred yards behind the two-seater. The fighter then has no chance of effecting surprise, is not in a position favorable for attack, and in addition may be under the fire of the flexible gun. Many types of hostile two-seaters may be attacked from the front and above, or on a flank from above, without exposure to the flexible gun. If any of these attacks be prolonged into a dive past the hostile airplane the fighter will be exposed to the flexible gun.

Attacks from ahead upon the flank are often successful as the vital area of the hostile plane is directly exposed. In an attack upon the flank, the fighting plane approaches under cover of the wing of the hostile airplane, or dives below the level of the two-seater out of gun range and then, with the excess speed acquired in the dive, drives in on the flank in a sharp zoom. The zoom from the lower level is timed to the speed of both airplanes, so that the fighter reaches the top of its zoom with gun sights on the hostile airplane at close range. The opportunity for gunfire from this position would usually be very brief because the fighter, in continuing a normal flight path, is soon obliged to avoid colliding with the hostile airplane. The fleeting opportunity for fire from this angle is prolonged by skidding the fighter. As the fighter nears the top of its zoom and opens fire, it drops the wing on the side toward which the hostile airplane is flying, and gives full rudder on the other side. Properly executed, this maneuver doubles or triples the time usually permitted for effective fire.

Ineffective fire in an attack of this nature leaves the fighter the choice of two maneuvers. The fight can be broken off by a wing-over and a dive in a direction opposite to the line of flight of the hostile airplane. A fighter persisting in the offensive ends its attack in horizontal flight under cover of the wings and fuselage of the hostile airplane, and seeks another opportunity for an attack in a blind angle. A second attack of this nature should be supported by other fighters. The fighter making such an attack without either surprise or support presents an excellent mark to the flexible gun of the two-place or multiplace plane.

Inverted flight. During the World War, a stock rumor circulated among flyers on both sides was that the latest fighting plane of the enemy had made an "outside" loop, which is a loop completed from a dive instead of from a climb, the pilot being on the outside instead of the inside of the circle. The story was never substantiated, and it is believed that in 1928 the first fighting planes were constructed that were able to carry out this maneuver.

The fact that modern fighters are enabled to change flight *in any direction whatever without stalling* opens up vast possibilities in the tactics of fighting. The business of "out-guessing the other fellow" becomes just twice as complicated as before.

Consider the case of a fighter diving directly away from a pursuing plane. Formerly, he had the choice of three different courses. He could turn, he could dive, or he could abruptly climb. Having abruptly climbed, he could then con-

Courtesy Bureau of Aeronautics, Navy Department.

THE U.S.S. "LEXINGTON"

tinue into an Immelmann, a wing-over, or even into looping over to a position behind the pursuer (provided the latter allowed him to do so.) In any case, it was a simple matter for the pursuer to maintain his advantage, simply "beating the other to the punch," and doing exactly what he did at the exact moment necessary to counteract. Now, however, a fourth choice is open to the pursued plane. He may continue the dive into inverted flight *and continue flying and fighting on his back.* If the pursuing fighter is not unusually alert, the enemy plane may return inverted on the lower platform and pour in upon him a disastrous fire before the pursuer has changed his course. The obvious replies to such a maneuver may be imagined, but one may also imagine further movements on the part of the pursued plane that may easily reverse the original positions.

The fact that modern fighting planes are enabled to fly, climb, and fight inverted does not necessarily mean that a combat pilot is going to carry out a whole set of complicated movements "upside down." In an extreme case it might mean that but the important consideration is that he is *ready at any instant* to continue normal flight into inverted flight, in which position he is just as dangerous as before.

It is not necessary to go into detailed descriptions of various situations in order to see that the modern fighting airplane has doubled the possible fighting maneuvers.

Fighting Pilots of the World War

The fighting pilots of the war can be placed broadly into three classes. These three groups reveal to a certain extent the stages through which aerial combat passed, and may be taken as indicative of the progressive development of aerial tactics. It must be remembered that the first combat pilots were without precedent. Their mission alone was clearly defined. The methods they employed were peculiarly their own.

The first type is best represented by Captain Ball, the first great British ace, and Captain Guynemer. They knew neither fear nor caution. Fighting alone, by preference, they unfailingly forced combat, impetuously engaging an enemy formation of twenty planes with the same ferocious, smashing attack with which they greeted a single opponent. Their sheer audacity carried them along to victory. An enemy sighted was an enemy to be engaged by direct approach along the shortest line, without regard to position or odds. This method of combat enabled Guynemer to gain fifty-three victories and Ball, at the age of twenty, to be officially credited with fifty-four enemy planes. But their rash self-exposure to enemy fire returned them to their hangars many times with their planes and often their clothes riddled.

Colonel Bishop and Major Lufberry are representatives of the second group. Their tactics were very similar to those of the first group. But where the first group forced the issue under any circumstances, Bishop and Lufberry tried first to shape conditions to their advantage. Their tactics were a strange admixture of caution and judgment, impatience and recklessness, in which impatience often dominated and drove them to assume the precipitate method of Ball and Guynemer. Lufberry was brought down in flames after eighteen victories. Bishop was withdrawn from active service with a record of seventy-two.

Clearly defined from the two preceding groups there stands the highly developed, perfectly balanced type led by Lieutenant Fonck and Baron von Richthofen. In these are found the same gunnery skill and flying ability, but allied now with coolness, infinite patience, and adroitness.

Neither Fonck nor Richthofen ever doubted the outcome of a combat, for once having joined they coolly harassed their opponents into an unfavorable position and then, and not until then, did they drive their attack home. They never risked the reception of enemy bursts by headlong plunges into the enemy fire. Fonck had a string of thirty-five victories before an enemy shot struck any part of his plane.

Solely as a contrast of methods, picture Fonck warily attaining the tactical advantage of an opponent before closing with him, and then witness the miraculous Guynemer with gun jammed beyond clearing repeatedly diving, unarmed, through bursts of fire, upon a two-place *Albatross,* until the gunner of the *Albatross* raised both arms and the pilot spiraled down to land on French soil a captive.

Fonck and Richthofen were fully as aggressive as the other classes of aerial fighters, as their records attest. Just as surely as they never avoided action or withdrew from it, they never permitted over-zealousness or impatience to subject them to blind exposure.

Captain Guynemer was brought down in 1917. His conqueror, Captain Weissman, met Fonck three weeks later. Fonck was in command of an offensive patrol of eight *Spads.* The patrol was flying at 20,000 feet, with Fonck in a commanding position 3,000 feet above the patrol. A two-place *Rumpler* appeared at Fonck's level and on his flank. Fonck circled, climbed, and maneuvered for position. The *Rumpler* accepted combat.

The *Spad* mounted a fixed gun, and was superior in speed, performance, and maneuverability. The *Rumpler* mounted a fixed gun and a flexible gun, thereby being superior in armament. The *Rumpler's* program was to keep the *Spad* out of blind spots in a line of fire. Fonck's problem was to keep beyond effective range until he could launch an attack in a blind angle.

The *Rumpler* went into a climbing spiral and opened fire at extreme range. There is no reason to believe that these tactics of the *Rumpler* were not the same that had accounted for Captain Guynemer. But where Guynemer had plunged to the attack in the face of a withering fire only to be stopped in his rush before he gained his objective, Fonck conceded the advantages of his enemy, and refused to close until he had made full use of the factors favoring him. The *Rumpler,* in maneuvering, was no match for the *Spad.* Fonck, keeping beyond effective range, soon gained the position he sought. A wing over, a dive, a sharp zoom, brought him under the tail of the *Rumpler,* blind to its gunner. There, at close range, a burst of six rounds gave him his fifteenth victory.

Caution, good judgment, and instinct shaped Fonck's tactics. His patience and flying ability gave him the position of vantage. Once he had closed, his marksmanship left no doubt of the outcome. The value of the high performance of the *Spad* must be placed neither too high nor too low. Experienced fighters considered a single-place fighter overmatched by a two-seater.

The tactics of the *Spad* in the encounter described are typical of the methods of Fonck, Richthofen, and their followers. Their more brilliant exploits reveal

the same canny fighting instinct and judgment, the same flying skill, the same expert marksmanship.

The morning of May 8, 1918, standing out as the high light of Fonck's career, serves further to illustrate the consistency of those tactics which carried him through seventy-odd combats. Flying alone at 20,000 feet on an early morning patrol he encountered and engaged a pursuit formation of five enemy planes, sending three down out of control in as many minutes. He returned to his hangar to examine his plane and to replenish his ammunition. Departing alone on another patrol a little later he surprised and destroyed an observation plane on its station controlling artillery fire. During the same flight he discovered below him a division of five *Albatross* observation planes on their way to a spotting station under the escort of four single-place fighters. Where Ball would have attacked either formation *en masse* and thrown it into confusion by diving at its center even with the risk of collision, Fonck centered on a single opponent, the rearmost escorting fighter. Diving several thousand feet with full throttle he effected an almost complete surprise and cut the rearmost fighter down, as both hostile formations swung to the attack. The disposition of the enemy was such that Fonck could not expend the momentum acquired in his dive in regaining altitude without undue exposure to enemy fire, for they were swinging to meet him even before he opened fire. He continued his dive and drew the attack of the entire enemy force. The very number of the enemy militated against them and assisted Fonck. He threw all his skill into the assumption of the defensive, to elude the enemy planes as they crowded to the attack. Anticipating the lull that would follow the attack of the last hostile plane he awaited his opportunity. As the last attacker drove past him, Fonck abruptly swung to the offensive and brought down his sixth plane that morning with a single burst. He lost considerable altitude in avoiding eight attacks and was at a tactical disadvantage deep in the enemy territory. The enemy force was unable to accomplish its mission without reënforcements to the escort, and these reënforcements could be secured only by a return to the base. Fonck sought no further encounter. In the six combats he had expended less than sixty rounds of ammunition.

Réne Fonck has often been asked to explain the methods that brought him his repeated successes. His answers have always been the same: that every combat progresses through certain maneuvers, that as the maneuvers develop, opportunities for attack are bound to be presented, that any one of these opportunities can be seized and an attack delivered without rash exposure. He admits a contributory effort toward the creation of an opportunity in certain cases. He denies the existence of further details and states that it is only necessary that one be in perfect physical condition. His conception of perfect physical condition, he explains, presupposes constant strict training. Granted mind and body in perfect accord, a total absence of fatigue, and the desire to fly, he assures us the result is inevitable; the enemy is defeated the moment he accepts combat, if one will only avoid rash exposure and seek opportunity for attack.

But Fonck has made no mention of his long arduous self-preparation, of his constant seeking for his own weaknesses and of his efforts to eliminate them, the continued application that resulted in his highly perfected flying and his unfailing marksmanship. It is here that all great fighting pilots meet on common ground.

Their individual tactics in the air may have varied, but their preparations for an offensive patrol were the same.

Their day's work began with inspecting and testing their plane, the testing and bore sighting of their gun, the calibration of every round of ammunition. Every part of the equipment, every unit that contributed to their success in the air received a painstaking examination. Spare moments found them studying their guns, effecting improvements, becoming intimately familiar with gun troubles, so that a stoppage in the air was at once instinctively analyzed and corrected. Idle days found them at the gunnery targets or perfecting their knowledge of the maximum performance of plane and engine.

Their determination to excel is manifested by their elaborate self-training throughout their careers. Yet these are the experienced combat pilots who developed present-day aerial tactics. Their devotion to duty, the qualifications they demanded of themselves clearly mark the line of endeavor for the pilot assigned to fighting-plane duty to whom the term "fighting pilot" means something more than a peace-time title.

The fighting pilot of today has the glorious traditions of the World War aces before him, and can accept as doctrine certain golden rules of aerial combat; but in the last analysis even he too falls into one of the three classes described. However complete his acceptance of the doctrines of successful tactics, basic mental and physical reactions to the heat of combat will decide whether he adopts the blind plunging of Guynemer or the coldly deliberate methods of von Richthofen and Fonck.

Whatever formation tactics of fighting we may adopt, the individual pilot in a single-seater will be the foundation upon which the formation tactics will be built. Formation combat is in its final analysis simply a combination of individual plane-to-plane fights.

Maxims for the combat pilot may be summarized:

Know that your ammunition, guns, and fuel are right.
Know your own and enemy planes.
Obey your squadron commander implicitly.
Take advantage of natural conditions.
Always try for a surprise attack.
Keep the whole sky under constant surveillance.
By your approach gain the greatest possible initial advantage.
Attack and fire first, without hesitation or delay.
Attack ahead while glancing to the rear.
Fire only at the closest possible range.
Persist in the attack until advantage is lost.
Avoid exposure to flanking fire.
Do not lose altitude except for a definite purpose.
Do not leave combat by moving in a straight line.

The Combat Pilot

Some futile attempts have been made to show that the combat pilot is an individual of radically different characteristics from the average. However, a careful survey of the most successful pilots engaged in pursuit work during the

World War indicates that those individuals were men of sound judgment, resourceful, energetic, and very aggressive in combat. As a general rule the pilot who is unusually fond of flying and has a sound physique, including good eyesight, steady nerves, and an active mind is the best type for this work.

Youthfulness, of necessity, will characterize the personnel of combat units and some authorities believe that the combat pilot should be little more than a boy. This may be sound if the flight and squadron commanders are older and more experienced men. If an organization is made up solely of youngsters, there is the danger of difficulties arising in controlling them in the air and obtaining coördinated efforts in carrying out instructions. It must be remembered that the combat pilot will always maintain a certain degree of individuality whether fighting singly or as part of a formation. This is quite essential in order to develop the proper degree of confidence in the ability of the individual to take care of himself under all conditions of combat.

Special qualifications of the individual pilot may be summarized as follows:

(a) Expert flying ability.
(b) Expert marksmanship.
(c) Ability to locate quickly and recognize aircraft in the air.
(d) Discipline in the air.

Expert flying ability will be developed to a great extent through the proper courses of instruction at the primary and advanced training schools. The proper flying ability can be developed if the individual thoroughly enjoys and continually practices acrobatics and other tests of flying skill. In order that the expert may not lose his "touch" he must continue to practice and try all maneuvers and "stunts" which may be required in combat. On joining the tactical unit the new pilot will be instructed by men experienced in the art of aerial combat.

Expert marksmanship. The ability of the combat pilot to shoot accurately is a qualification which cannot be too highly emphasized. Targets in the air are small and almost invariably fleeting, so that bursts, to be effective, must be delivered rapidly and concentrated within a very small area. Valuable training in this connection may be obtained through shooting at suitable ground targets located near the combat airdrome, and at towed sleeves in the air.

Location and recognition of aircraft. A qualification of equal importance to any other is the ability of the individual to readily see and recognize aircraft in the air. It is difficult for the inexperienced to realize the importance of this qualification and, unless great emphasis is placed on it throughout the course of training in the schools and with tactical units, unnecessary loss will result. Ability along this line will be developed through intensive training in observation of technical units in the air and through study of silhouettes of hostile aircraft.

Discipline in the air is a matter of training and the subordination of the individual to the unit. The present employment of combat in large units, such as squadrons and groups, makes it necessary that the individual pilot be trained in strict air discipline and impressed with the necessity for remaining with his organization regardless of conditions. This in a limited way destroys the individual initiative of the pilot that was so emphasized during the World War. In other words, the combat pilot is now a part of a smooth working machine rather than a spectacular individual.

Courtesy Bureau of Aeronautics, Navy Department

FIGHTING PLANE SQUADRON IN LINE

CHAPTER XI

FORMATION ATTACK

Definitions—Administrative and Tactical Groups

(1) **An aircraft squadron** is the basic unit of administrative and tactical command in the organization of air forces.

(2) **An aircraft division** is a major tactical subdivision of a squadron, normally consisting of nine planes.

(3) **An aircraft section** is a tactical subdivision of an aircraft division, normally consisting of three planes.

(4) **A pair** consists of two airplanes, generally of the same type operating together.

(5) **A group** is a tactical command consisting of a number of aircraft squadrons either of the same or of different types.

(6) **A wing** is an administrative command consisting of all the aircraft of a certain type attached to a fleet.

(7) **The air force** consists of all aircraft attached to a fleet.

Task Forces

(1) **A flight** consists of all the aircraft which operate together for the accomplishment of a single mission.

(2) **A formation** consists of a number of planes flying in an assigned position with reference to one another.

(3) **A unit** is a body of aircraft which operate together on visual signal from its commander.

Example—Six *VS's*, eighteen *VT's* and thirty-six *VF's* are dispatched to locate and bomb a certain enemy force. The whole constitute the flight. The six *VS's* flying ahead in pairs at 10 miles distance between pairs constitute a formation. Each pair constitutes a unit. The eighteen *VT's* flying in squadron-bombing formation constitute a formation. Since they are all controlled by visual signals by the squadron commander, they also constitute a unit while in formation. The thirty-six *VF's* fly in divisions, each maintaining a certain direction from a common guide. Collectively they constitute a formation. Each division in this case constitutes a unit.

Dispatch of Air Flights

(1) **The commander in chief** or senior officer present ordinarily initiates air operations.

(2) **The senior air-force commander** ordinarily designates the air units which are to conduct such operations and the general method of their procedure.

(3) **The senior officer of the air forces** assigned to the conduct of the operations is in direct command of the air forces detailed for the purpose as soon as they take the air.

(4) **The senior officer of each tactical unit** is in direct command of that unit as soon as it takes the air.

Communication

Radio is the primary means for communicating between ship and aircraft, and between aircraft. The dot and dash system is commonly used, but the telephone will probably come more into use for communicating between aircraft. Various kinds of visual signals have been tried out. Some remained in use for awhile, but generally speaking visual signals are not very satisfactory for conversing back and forth. However, when used as a display signal such as a Very star, smoke ball, ground strip, or light, they may be very useful to indicate some particular meaning.

Origin of the Formation

The evolution of the fighting formation has been gradual, much more so than the application of the airplane to warfare.

A report of the German general staff written in October, 1914, contains the following assertion; "The duty of the aviator is to see, not to fight." The following month Captain Nestroff, of the Russian air force, who had made the first loop in 1913, contested this statement by deliberately ramming an Austrian bombing plane. This was the first aerial fight that ended decisively. Airplanes on the Western Front were in the process of transition from the stage at which opposing pilots greeted each other with a wave of the hand, to the point of development at which the machine gun was installed. It was with the installation of the fixed machine gun that the single-place fighter came into being as a distinct type.

There ensued a long period of free lance operations by fighting planes. Pilots were taught to fly and shoot and then sent to the front. There they were given a fighting plane and dispatched on their mission to destroy hostile planes. Their methods of accomplishing their mission were of their own forming.

Group flying was inaugurated by the German Captain Boelke. It was a natural outgrowth of his own ability and experience. A skilled pilot himself before the war, he sought, by means of the formation, to give his command the advantage of his leadership, to provide concentration, and to indoctrinate his less experienced subordinates before subjecting them to isolated contact.

The value of Captain Boelke's early formations may be measured by the heavy toll they exacted from the ranks of the free lance fighters of the Allies. All belligerents then carried formation flying to the extreme. Single formations of ten to forty planes were not uncommon, especially in the German air forces. Formation flying reached its highest development perhaps in the famous Tango Circus of Richthofen. To the swashbuckling antics of the aerial circus which earned this squadron its name, there were added unfailing leadership, precise flying, and thorough coöperation of pilots in an attack. The efficiency of Richthofen's organization downed 194 Allied planes in six months.

As the methods and the results of the work of the highly skilled individual fliers became better known, both observation and combat pilots learned to give them a wide berth, and it became increasingly difficult to make surprise attacks from any angle. Therefore, planes went out in pairs, one of them acting as a decoy for the other. We are bound to admit much sympathy for the pilots who acted as decoys, because they were frequently shot down before their supporting pilots could dive to the rescue. It was, however, their willingness to act as decoys and the results of such methods that first showed the necessity for teamwork in combat tactics, and led to the adoption of the combat formation. Boelke first led a fighting formation over the lines and, after his introduction, the system of fighting in formation spread throughout the German and Allied forces.

From this time forward, differing methods of concentrating formations and of maneuvering them upon contact with the enemy were followed. In point of time there was no clear-cut division between the abandonment of one method and the adoption of the next; but for purposes of study we may consider that such division existed.

Formation Strategy and Tactics

One of the first duties assigned combat formations was the protection of observation planes. The protecting formations were ordered to adhere closely to the observation formations and were prohibited from leaving this close vicinity in order to attack an enemy force. Thus we may call this system the "close-protection" idea. The fallacy of this scheme of employing combat forces is evident. It is a violation of the fundamental principle of initiative. Aggressiveness, which is vital to combat success, was restricted or altogether lost.

After it was seen that the close-protection method of employment could not succeed, there came a demand for increased combat forces in order to allow a large number of airplanes to operate aggressively over the front within certain well-defined and rather narrow limits. This idea we will call the "barrage-patrol" method. The formations were stationed at specified altitudes, and swept back and forth over their assigned sectors. The formations were placed at high, intermediate, and low altitudes. The idea was to deny the enemy passage over the lines. The plan failed simply because it was physically impossible to cover all of the air at once, which is another way of saying that the barrage patrol violated the principle of concentration. The barrage patrol, however, was really the forerunner of our present-day close attacks but its natural elements of value were not at the time recognized.

Following the barrage patrol the "alert system" was adopted. Formations of all sizes and all types of planes were kept in readiness at various front-line airdromes to take the air at a moment's notice. Naturally the way of avoiding the attack of these formations was easy for the enemy aerial forces. The enemy would come over at altitudes of 15,000 feet or higher, using clouds for concealment, make his attack, do his damage, and be well on his way home before our formations could ever get in the air and climb to his level, much less get the desired altitude advantage of him. The system was essentially defensive. *There is no principle of the defensive.*

Courtesy Bureau of Aeronautics, Navy Department.

A Fighting Plane Squadron About to Take Off

At last we recognized the fact that attack airplanes must follow exactly those principles that apply to all land and sea forces. The only way combat airplanes can *defend* is to seek out the enemy and *attack*. The battle of the Somme in 1916 furnished the first example of attempt to discourage individual fighting and to employ combat planes in large formations.

At first a single leader would attempt to control as many as twelve or more planes in one flight; and it required regrettable losses to demonstrate that not more than five to seven planes can be efficiently controlled by a single leader in actual close fighting. It took some time to iron out this and other difficulties; so the exploits of individual fighters continued to overshadow formation tactics until the fall of 1917 (in the American service, indeed, throughout 1918). The next development in the use of formations was the echelon. The adoption of the echelon (line of bearing) was really the one thing that made formation fighting possible under all conditions. The "V" formation is an excellent formation for cruising, and is the basic formation of airplane tactics, from which all other formations are taken and upon which all formation tactics are based. However, the "V" formation does not lend itself well to close attack. There is too much mutual interference between the planes, and there is the added disadvantage that the planes converging upon a single point are most liable to collide.

With the use of the echelon, large formations were built up called "chains of flights." Flights were stepped up in altitude one behind the other, thrown out to either side of the leader on quarter bearings, and proceeded to enemy country, attacking whatever enemy formations they could find. Thus at last the proper principles of aerial fighting were recognized and control of the air was procured for the Allied forces. This system of using fighting formations was the system in vogue at the time of the Armistice. It is from this point that we have gone forward in the fleet.

Perhaps the most important development that we have made has been the adoption of the three-plane unit. Each division, each squadron, each group, is built up of three-plane units. All compound formations and their maneuvers simply consist of various dispositions and movements of three-plane units instead of dispositions and movements of single planes.

The many variable factors, such as the approach, spacing, type, disposition and number of hostile forces, degree of visibility, presence or absence of clouds, etc., will all have a very important influence upon the method of attack adopted by the unit commander upon the spot. There are, however, certain principles involved which may be outlined here and which each unit commander will endeavor to follow if conditions permit. It must be remembered that the high speed of fighting airplanes and their great maneuverability cause the situations to change with tremendous rapidity. A fleet of surface craft may maneuver all afternoon for the sole purpose of gaining one tactical advantage. Between two formations closing for combat the tactical advantage may be lost or gained several times in the course of fifteen minutes.

Certain weather conditions are frequently referred to as limitations on the activities of air forces. These so-called adverse conditions may be turned to account by a combat commander. He may take advantage of a low-hanging fog to conceal his movements, remaining in the fringe of the top stratum until he

is in favorable position for attack. He may use clouds for the same purpose, or for the purpose of hiding in order to effect ambush.

Sunrise and sunset offer conditions for concealment which are diametrically opposed to the old principle—"Keep the sun at your back." During the hours of twilight the glow of sunlight on the horizon gives a background which makes concealment of aircraft impossible when approaching from the direction of the sun. Consequently, approaches to targets at daybreak and immediately after sunset should be made towards the sun.

The use of the sun from which to approach, counting upon the glare to blind the enemy, is, of course, of great importance. However, the blinding area of the sun's rays is very small and infinite care must be exercised in handling formations if it is to be used to any advantage.

The various wind currents at differing altitudes may be used to some advantage by a combat commander to more rapidly or more slowly close any other formation in the air.

The approach is an all-important phase in combat. The whole fight may depend upon the type adopted. The commander must by his approach gain the utmost advantage of the enemy before the two formations have closed to effective gun range.

In addition, we may enumerate other important factors:

(1) Altitude advantage—a factor of decisive importance, and must be sought under all normal conditions of combat. In single-seater versus single-seater fighting, the altitude advantage is the vital tactical advantage sought.

(2) Determination is a factor of the highest importance. Every attack, once launched, must be followed through with the utmost determination until the enemy is shot down or forced to retreat from the fleet battle area.

(3) The firing range must be closed to a minimum. With the present equipment this means to within 100 feet. As our gunnery material improves, effective ranges may possibly be increased but this is doubtful.

(4) Attacks on pursuit forces must be made with suddenness if surprise is to be obtained, each individual concentrating his fire on one airplane of the hostile formation.

(5) Attacks on an enemy formation must be made simultaneously from as many angles as possible, every effort being made to close in on enemy blind sectors, which are sectors in which his fire is screened.

The mission of the fighting plane is ever the destruction of hostile airplanes. A specific mission such as the protection of spotting or observation planes merely limits the extent of the offensive operations of the fighting plane. Offensive operations they must be, because the defense of the fighting plane, its speed and its power of maneuver, protects nothing but itself. Every enemy entering the area occupied by the screened force must be met by a concerted driving offensive by the screening fighting plane. The mere presence of the fighting planes flying in formation will serve only when in such superior numbers that the enemy hesitates to attack. This condition will seldom, if ever exist. Fighting planes are undoubtedly vulnerable if they retain a normal formation when attacked. Such an

action is fatal not only to the fighting plane but to the success of the mission of the screened force.

The fighting plane operates singly only under certain special conditions, when in contact with the enemy. Bad weather with its low-hanging clouds will permit single fighting planes to be dispatched on individual missions of penetration of the enemy screen seeking formation. Under these conditions fighting is avoided.

Attack Upon Surface Craft

Attacks on surface craft and kite balloons are made by fighting planes employing light bombs and machine guns during periods when command of the air is being exercised. Such attacks made in the face of an enemy air offensive result in losses that overbalance the damage done to the enemy.

The demoralizing effect of any attack by fighting planes in large numbers upon tops and bridges of enemy vessels is very great. The actual material damage done by a concerted well-directed attack centered upon these vital areas may be even greater.

The general situation, the weather, and the number of fighters available for the mission determine whether the planes are dispatched singly, in pairs, or in formations.

The safety of the attacking planes lies in rapid movement. The attack must never be made in such numbers that some planes are required to wait their turn to attack. Any such procedure will greatly increase the losses of the attacking formation. It must be clearly borne in mind that complete surprise of a battleship by a fighting plane, even when followed up by accurate gunfire on tops and bridge, does not grant the fighter the immunity from damage that parallel conditions would create for the fighter against the opponent in the air. The damage that may be inflicted upon the enemy by attacks at the vital areas is so great, however, that it will always justify the losses suffered when made under conditions favoring the attacking fighters.

Missions of this sort can be given the fighting plane when clouds prevent hostile protective patrols; when visibility is poor; before dawn, at dusk, and at night; and when it is known that very few hostile airplanes are active in the air.

Attack Upon the Kite Balloon

Kite balloon attacks are of two kinds: (1) the free lance attack by a fighting plane which finds an opportunity to attack after the conclusion of another mission; (2) the carefully planned formation attack.

The first type of attack is made with great danger to the attacking plane and is likely to achieve success only under the most favorable circumstances. This attack consists of a single dive, a burst of fire at extreme range and prolonged to close range, then immediate withdrawal. The forward part of the kite balloon is the point of aim. Bursts fired into the after third of the bag do no damage as that portion of the kite balloon contains nothing but air upon which incendiary ammunition has no effect.

All attacks on kite balloons must contain a certain amount of the element of surprise, lest the attacking force find its target gone upon reaching its objective.

Surprise is more easily achieved and aerial resistance is reduced by attacks made before dawn, or at dusk.

The balloon may be protected by hostile airplanes. The formations taking part in the attack are disposed to ward off any aerial resistance. The attack may be delivered by a single plane or by three planes or five planes in formation. The single plane or a formation of three, are preferable to larger groups because of less mutual interference. The actual attacking unit is supported by one or more fight formations. Rendezvous is effected at the objective or in its immediate vicinity. The approach of a large number of fighting planes will cause the enemy to house all kite balloons. To prevent this, the attacking force and its support proceed independently to the objective. The attacking force closes in at the designated time, and is reënforced by the support formation a minute or two later. The supporting fighters must meet the resistance of hostile airplanes protecting the kite balloon so that the actual attacking unit is left free to deliver effective gunfire. The attacking unit drives into close range down wind and pours a hot burst of incendiary ammunition into the nose of the gas bag.

Fighters attacking kite balloons encouter the same destructive gunfire from the surface that is met in attacks on surface craft. This surface resistance is more dangerous to the fighter in this case than it is when the attack is centered upon the vessel itself. A plane intent upon attacking a balloon 1,000 or 2,000 feet aloft is a better target for the vessel than the same plane maneuvering close aboard and attacking the vessel. Besides the altitude is accurately known. Attacks on kite balloons are, therefore, never prolonged sufficiently to permit the full development of surface gunfire. The formation will serve to cause some dispersion of this fire, but the fighting plane is at too great a disadvantage to persist for long when met by an organized fire from the surface. The attack must be thoroughly planned, well timed to effect surprise, and rapidly and accurately delivered.

Attack Upon Dirigible Airship

The most effective method of attack upon a dirigible airship is with bombs. Release can be made from such a low altitude as to make missing almost impossible. There is no problem of windage, and longitudinal run eliminates the one of speed. The bombs themselves could be as light as twenty-five pounds. Fighting planes can carry two such bombs without seriously affecting their performance.

Prior to the advent of the modern combat plane, airships, when attacked, sought protection in a rapid attainment of altitude at a rate of climb in excess of that possible for any heavier-than-air aircraft developed during the war. This means of defense is no longer possible in consideration of the rate of climb of the latest pursuit planes, which, at the present date, is in excess of 2,000 feet per minute.

In the formulation of a doctrine for the attack by single-seaters on airships inflated with helium, the use of the incendiary bullet still plays an important part. The rupture by machine-gun fire of any of the fuel tanks carried in the hull of the ship might be sufficient to put it out of commission. Until heavy oil is used as a fuel for dirigible engines, gasoline fires will always be a serious menace.

Conclusion

As a matter of interest it may be cited that the remarkably successful exploits of the well-known flying circus, commanded by Richthofen, were attributable to the rigid adherence to doctrine of all flying personnel under his command. Stations of pilots in the combat formation were made with reference to flying experience and marksmanship. To those of least flying experience were assigned stations in the middle of the formation. Flying well above the main group were those especially selected pilots, including Richthofen himself, qualified as expert aerial marksmen. The mission of the main group was to close with any enemy aerial force encountered, while the special formation held station and reserved fire until one or more of the enemy planes engaged below lost control, or for any reason separated itself from the general mêlée. A part of the upper group then dove, with full power, and subjected the isolated enemy to a raking and destructive machine-gun fire.

Courtesy Bureau of Aeronautics, Navy Department.

NAVY AMPHIBIAN

The *OL-8,* for use from carriers or other types of surface vessels.

CHAPTER XII

AERIAL GUNNERY

The fighting pilot went back to paleolithic weapons in first arming for aerial combat. It is officially recorded that two airplanes were brought down in 1914 by well directed rocks. These primitive weapons were soon laid aside in favor of the automatic pistol, the rifle, and the shotgun.

Four months after the introduction of aerial fighting, the Lewis gun appeared, mounted on the upper center section of the *Nieuport,* with its bore parallel to the longitudinal axis of the plane, and its trajectory clearing the propeller. This installation permitted the pilot to bring his sights on by maneuvering the plane but required him to land to change magazines, a considerable disadvantage when it is remembered that only the small forty-seven round magazines were then in use. The pilot was equally unable to remedy any gun failure while in flight. This installation was later modified by mounting the Lewis gun on a rail at a point over the cockpit within reach of the pilot. The pilot was able to slide the gun down the rail to a position that permitted his changing magazines and correcting gun troubles. The gun was drawn down by the pilot against the tension of rubber cord which returned the gun to battery. The mounting was very successful and was retained even after synchronizing gears were introduced.

The fixed machine gun firing through the propeller was introduced when aerial fighting was six months old. Credit for its inception goes to Roland Garros, foremost of the French flyers before the World War. Garros employed wedge-shaped steel plates on the propeller blades which deflected the 5 to 10 per cent of the bullets which struck the blades. A whim of fate forced Garros down in enemy territory about two months after he introduced this device, thereby causing him to personally deliver his innovation, intact, into enemy hands.

Ten weeks after Garros' capture the German *Fokker* appeared, mounting the first synchronized machine gun. The synchronizing gear eliminated the loss in propeller efficiency caused by the deflection wedges and in effect increased the volume of fire.

The next step taken to increase volume of fire was the introduction of twin fixed guns. Twin fixed guns remained in use scarcely two weeks. The second gun meant added weight. It was tried, found to decrease plane performance, and was, therefore, rejected. Here is clear evidence of the refusal to sacrifice fighting-plane performance even to a component as vitally important as volume of fire. When aviation engines began delivering more than 200 horse-power, the twin fixed gun reappeared and was fairly widely installed.

A brief consideration of the machine gun and its ammunition brings out the fact that both were originally intended solely for employment against personnel. The adaptation of the machine gun to the airplane has not increased its effectiveness when employed for the destruction of anything other than personnel. Granted even the use of armor-piercing, incendiary, and explosive bullets, a hostile plane

is brought down in the large majority of cases by the death or serious injury of the enemy pilot.

In any case a blow in a vital spot is necessary to bring the enemy down. The total vital area, including engine, fuel tank, and pilot, represents only about one-tenth of the target presented.

An aerial fight is decided usually at ranges between 50 and 100 yards, and always at ranges below 300 yards, and this by a weapon of a normal effective range of 2,000 yards. A hostile plane may be subjected to the most scathing machine-gun fire by the most destructive types of ammunition, its wings, engine, gas tank, fuselage, and tail surfaces hit many times, and still the enemy's most valuable possession—the pilot—may escape. Light armor constructed by laboratory methods will efface the vital spot entirely. Machine guns, already overmatched by the unarmored plane, may soon be wholly inadequate if experiments in armor are successful.

The first step toward increasing the effectiveness of fighting plane armament was taken by Captain Guynemer in July, 1917, two years after the appearance of the synchronized fixed machine gun. Guynemer had thoroughly demonstrated his marksmanship in downing forty-eight enemy planes. Most of these duels had been won with a burst of about ten rounds, several with three or four rounds, and one with a single shot. On the other hand, many hostile planes with their pilots had escaped destruction even though struck with well-directed bursts, simply because no hit had reached the vital spot. The destruction of the enemy pilot and plane could be assured only by direct hits on the pilot. Guynemer had reason to be convinced that the machine gun was not the most effective weapon that might be employed against the hostile aircraft. He proposed the construction of a fighting plane mounting a 37-millimeter (one-pounder) gun firing through a hollow propeller shaft. It required several months to convince the authorities that any such change in armament was necessary or practicable.

A *Spad* was equipped with a geared 200-horse-power engine, the propeller revolving on a hollow shaft. A semi-automatic 37-millimeter gun weighing 100 pounds was mounted on the top of the crankcase at the bottom of the engine "V," with its barrel and slide projecting through the propeller hub. The muzzle velocity of the 37-millimeter gun was reduced below its normal 1,800 f.s. to lessen the shock of recoil. A practically flat trajectory of 300 yards was obtained for an explosive projectile five times the diameter of the 0.30 caliber machine-gun ammunition.

The weapon was first employed over the Battle of Flanders, July, 1917. Captain Guynemer opened fire on a two-place observation plane at a range over 200 yards. The first shell struck the hostile plane in the tail and sent it down in flames.

The advantage of the 37-millimeter gun, or a gun of larger caliber, over the machine gun is apparent. The automatic one-pounder firing 60 shots per minute will deliver 60 pounds of metal per minute as compared to 7 pounds per minute for the machine gun with a rate of fire of 400 per minute. Any one hit by the one-pounder may suffice to destroy the structure of the enemy plane, whereas the 7 pounds delivered by the machine gun can be expended through the hostile plane without serious damage. More general employment of this type of weapon

will depend, as all earlier increases in armament have depended, upon the degree to which it affects the performance of the fighting plane. It is likely to find a place only on the planes of large weight-carrying capacity. At present the armament of the fighting plane consists entirely of machine guns of 0.30 and 0.50 calibers, both used against personnel and structure of the enemy aircraft.

For purposes of sight design, a gun is either fixed or flexible according to whether or not its line of fire coincides with the flight path of the airplane. Any machine gun that has its line of fire in a direction other than that of the line of flight is a flexible gun and requires flexible gun sights, without regard to the degree of freedom of elevation, depression, or train, permitted by the installation.

The **fixed gun** is always so mounted that the axis of its bore is parallel to the longitudinal axis of the airplane, and thereby practically coincides with the line of flight. The gun may be synchronized to fire between the blades of the propeller, or may be mounted on the upper wing with its trajectory clearing the propeller blades. The gun is operated by the pilot, who brings his gun to bear by maneuvering the airplane.

The **flexible gun** is mounted on a Scarff mount in a gun cockpit. It is free to move 360 degrees in azimuth, 90 degrees in elevation, and approaches 60 degrees in depression.

Tunnel guns firing downward through a tunnel in the fuselage are installed on large multiplace planes. They provide effective fire in the arcs that are beyond the fire zones of the other fixed or flexible guns on the plane. Their freedom of movement is restricted and differs in degree for each installation. Their operation requires a gunner.

Bracket-mounted guns, which are hung out through sliding panels in the sides of the fuselage, serve the same purpose as the tunnel gun. They possess greater freedom of movement than the tunnel gun but considerably less than the truly flexible gun.

The ammunition used for these guns is of four types: service, tracer, incendiary, and armor-piercing.

An apparent necessity for tracer ammunition in aerial combat is evident when the variables of aerial gunnery are investigated. However, tracer ammunition is used with great caution in the fleet squadrons, and not at all by many squadrons. The results of many practices have shown that greater accuracy is obtained by precluding its use and placing entire dependence upon the sights. The trajectory of the tracer projectile usually differs from the path of the solid projectile, and in many cases is entirely erratic, thereby leading the gunner to false conclusions. Many gun stoppages, moreover, have been found to be due to loose tracer projectiles, or poorly calibrated tracer-cartridge cases.

A machine gun fired from an airplane is operating under conditions considerably different from those met by the same gun when employed on the surface. The surface gun is normally stationary and is fired at a stationary or slowly moving target. In aerial use the machine gun is fired from an airplane which is usually moving at a speed of more than 100 miles per hour at a target moving at a similar speed. Aerial ranges are so short that the factor of elevation is disregarded. Effective aerial fire is seldom delivered at a range greater than 200 yards.

There is no problem of windage. Whatever the wind may be, it equally affects

the gunner's plane, the aerial target, and the bullet. All three are operating in the same medium.

The speed of both the gunner's airplane and the hostile airplane varies rapidly through wide ranges. The speed of either is at once changed by an increase or decrease in engine revolutions, by diving or climbing—evolutions which are a part of any aerial fight.

Since relative speeds of 200 miles per hour are not exceptional, it is apparent that the opportunity for fire is very brief. Two airplanes with speeds of 100 miles per hour approaching each other on opposite courses present only a five-second opportunity for fire through all ranges. This extreme condition permits a burst of sixty to seventy rounds. Other angles of approach reduce the relative speeds of the planes but the time permitted for aerial fire is always very short. Airplanes engaged in combat constantly change their plane of flight. This factor, in conjunction with the rate of change of range, is a matter of constant concern to the gunner.

Altitude directly affects the speed of the airplanes. Because of its effect on airplane speeds, altitude causes variations in the rate of range. Altitude also slightly affects the time of flight of the bullet and thereby contributes to the inaccuracy of fire by causing variations in the deflection necessary to secure hits upon a given plane at different altitudes.

A burst of fire from a flexible machine gun produces an elliptical cone of fire with axes approximately twenty and thirty feet at 200 yards. The cone itself is a product of jump, drift, varying powder charges, personal errors, and lack of rigidity in the gun mount.

In their present state of development aerial gun sights are only an aid to the judgment of the gunner. The problem of deflection due to motion of gun is only present in the flexible gun. The front sight of the flexible gun has a wind vane attachment which uses the air speed of the plane to automatically correct this error.

In the case of both guns the problem of deflection due to target speed must constantly be solved by the gunner. A ring, similar to a peep, around the sight, indicates the correct deflection for a definite target speed.

The gunner must judge the actual target speed and apply mentally the correction. In any case the sight is placed in such a position that the target's line of flight crosses the center of the ring. If for instance, the target speed is judged to be greater than that for which the ring is designed, the gunner places the center of the ring directly ahead of the target but far enough ahead to place the target outside the enclosure of the ring.

It has been stated that so long as the gunner confines himself to aerial targets he need not concern himself with the wind. However, when he directs his fire at a target which is on the surface, or supported from the surface, the speed of the wind and the speed of the target both require compensation. In this case the deflection allowance depends upon the ground speed and not upon the air speed. The wind vane sight compensates for the air speed of the gunner's plane, leaving the correction for the real wind to be corrected for by the gunner's point of aim. In the case of a moving surface target the speed and direction of the target, and the wind speed with its direction reversed are combined, and the re-

sultant speed and direction of movement compensated for by shifting the point of aim. In firing upon surface targets, the aerial gunner is usually able to watch his bursts take effect, and can spot them on the target.

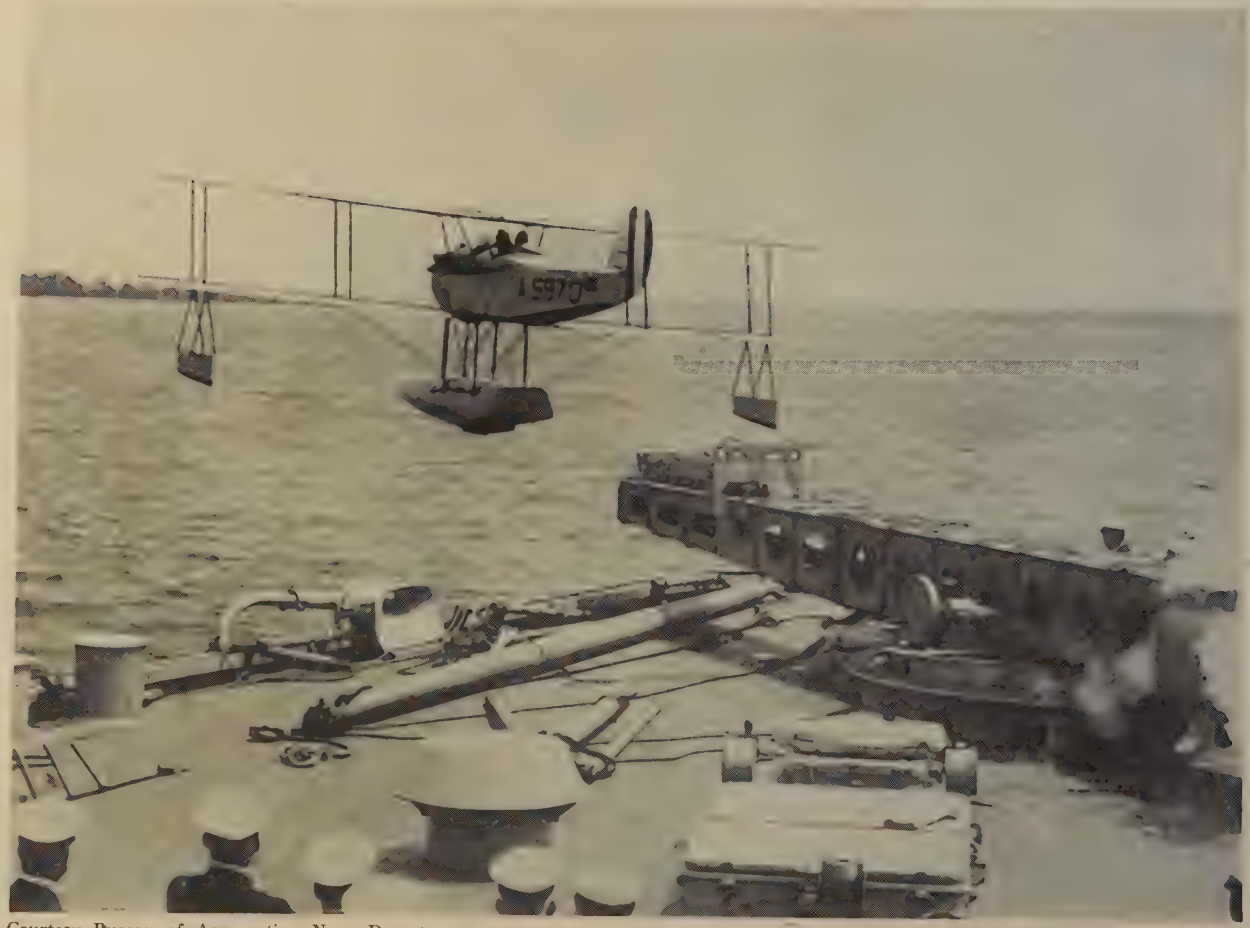
Fire Tactics

The comparative ineffectiveness of the aerial machine gun must be clearly understood. If there is one cardinal rule to govern the tactics of the fighter it is that the probability of deciding an aerial fight increases with every yard the range is reduced. This fact does not condone blind self-exposure. It does emphasize the need for expert marksmanship and full utilization of the power of maneuver. The effective use of weapons can be placed secondary to no other factor of success. The mission of the fighting plane pits it against the hostile spotter, the hostile observation plane, the bomber, and the torpedo plane, as well as against the fighter. If success is to be achieved by the fighter the hostile fighter must be closely matched in inherent plane performance and plane armament.

Greater personal skill in employing power of maneuver, and more effective use of weapons will decide the fight. The effective use of weapons depends in part upon power of maneuver utilized to attain a position for attack. But no amount of skill in flying can compensate for any weakness in marksmanship. Brilliant flying often has permitted a pilot to engage an enemy and later to withdraw from the fight, which his limited marksmanship was unable to decide. This, however, is not the mission of the fighting plane. Its mission is the destruction of the enemy, not self-preservation by a brilliant defensive. The fighting plane which cannot make decisive use of opportunities for effective fire created by the pilot's flying is more valuable housed in its hangar. Its offensive value is potential, not actual. The hostile fighter is the most vulnerable opponent the fighting plane has to encounter. The hostile observation plane, torpedo plane, bombing plane, and patrol plane all have the fighter overmatched in armament.

All types of airplanes present practically the same vital area. It is only the superficial area that is increased in the bomber and similar types. This apparent size of the target misleads the attacker and weakens his chances of success.

The importance of effective gunfire must not be underestimated. Brilliant flying, always desirable, is secondary to the effective use of weapons. This has been conclusively demonstrated. Moderate flying ability and effective gunfire will always defeat ineffective gunfire even though it is accompanied by the most accomplished flying. It is an interesting commentary upon the men who have written their names boldly across the pages of aerial history, that despite their unquestioned success, not one of them considered his marksmanship quite satisfactory.



Courtesy Bureau of Aeronautics, Navy Department.

OBSERVATION PLANE CATAPULTED FROM BATTLESHIP

CHAPTER XIII

OBSERVATION

One of the most important functions of the aircraft is the observation of gunfire of surface craft. The aircraft affords a position far superior to any other for observing long range firing.

Records of the Gunnery Exercises Office indicate that in spotting practices held during a recent gunnery year the average spotting error of all aircraft was 90 yards, something less than one-half the average error of the ships, which was 200 yards. Based upon the accepted methods of computing effective volume of fire, a decrease in spotting error from 200 to 90 yards represents in itself an increase of approximately 16 per cent in the volume of effective fire. This is equivalent to the addition of at least one capital ship to our fighting force. One point that should be remembered in this connection—and a most important one—is that spotting practices are held under most conditions of comparatively fair visibility, and that the ship is working under much less difficult conditions than may be expected to obtain in actual service firing. So is the aircraft, of course, but low visibility is usually a much more serious handicap to an observer on the firing ship than to one in the aircraft. Frequent cases have been recorded in reports of target practices where the target has been completely obscured from the maintop spotter. In addition to this, it must be remembered that the ship's spotting error inevitably increases with increases in range, while the aircraft's estimate is in no way affected by the range. How important to the fleet has become the aircraft as an observing station and how much reliance is being placed in it is evidenced by the fact that in target practice in cases where the aircraft's estimate differs materially from that of the ship, the aircraft observation is usually accepted without question. This is a state of affairs that has been brought about solely because the ship has learned by experience that the aircraft observation is probably the correct one. This is not a matter of personnel. It is purely a function of the superiority of position for observation—the high spotting-platform idea carried to the limit.

Until the advent of aircraft, it had been practically impossible to open or maintain effective fire unless the target was visible from the firing ship. In cases of low visibility the range was reduced. A well-laid smoke screen had been considered as putting an end to effective gunfire, and had, therefore, been thought of principally as a defensive measure. By the use of aircraft as an observation platform, it becomes entirely practicable to fire with fair effectiveness under conditions where the target is completely obscured from the firing ships.

In this one field of endeavor alone, the aircraft appears fully to justify its existence. Obviously a fleet having no aircraft observers cannot but be at a hopeless disadvantage when engaged with an otherwise equal fleet which has well-organized aircraft spotting. This is not merely an interesting conjecture; it is fact, a fact which is, perhaps, even yet too little realized by the Navy as a whole.

So much for the inherent potential strength of aircraft in increasing the effective volume of fire of first line ships. What of the weaknesses?

The greatest weakness lies in communications, partly in the material itself, but principally in the development of methods of using it which will insure getting the right information to the right persons at the right time. It is a simple matter for the aircraft spotter to estimate accurately and instantly the proper correction. It is far from simple, in the confusion of battle, for him to get his information to the particular corner of the firing ship where it can be effectively applied. It has been repeatedly demonstrated that this can be done in the case of individual ship firing and in division firing under target-practice conditions. In these conditions it has been found that the interval between the fall of a salvo and the receipt of the aircraft correction on the firing ship is somewhat less than five seconds. In concentrated fire under actual battle conditions, this is not so simple a matter. One of the chief difficulties when several aircraft observers are on station, a necessary requirement in actual battle, is first for each spotter to distinguish which salvos are his to spot, and second, for the ships to distinguish which observations received from the planes belong to each ship. Ships' observers have similar difficulties now, incidentally. A solution of this problem is procured by a confidential device which has been developed by the Bureau of Ordnance.

The method of employing the planes for spotting when the target is invisible to the firing ships is in general as follows: the aircraft proceeds to a point from which the target is visible, and transmits by radio to the firing ship the approximate bearing, range, course, and speed of the enemy. With these data, a series of ranging salvos is fired, using gyro bearings and stable zenith indicator as reference planes for deflection and elevation. As each ranging salvo is fired, the aircraft transmits corrections until the firing ship is "on," at which time the correct sight-bar readings are transmitted to the other ships, and the whole force opens fire. Once fire is successfully established redistribution can be made to include all enemy ships.

The spotting planes are disposed in two formations. By keeping in formation the planes offer mutual protection. The normal altitude is about 10,000 feet, but when the visibility is poor the formation seeks the greatest altitude from which all targets are visible.

In a case like this where more than one ship is firing at a single target, the spotter is not affected except that he has more work to do. He continues to spot every salvo. It is for the firing ships themselves to pick out their own spots. The spotter aids the ship in so doing by transmitting a dash as soon as a salvo lands, followed immediately by his spot for that salvo. Each ship can thus pick out its own spots by the aid of the "time of flight clock."

If the enemy is visible to the firing ships no such arrangement is necessary. The commander in chief signals the distribution of fire. At the order to commence firing, each ship opens fire on its assigned target in the usual way with its own data. The spotting planes, as before, guard their individual zones.

Indirect control of gunfire of surface craft by aircraft is now only in its beginning. Already it has made its influence strongly felt, as is evidenced by reports of increased accuracy and assurance almost universally voiced in reports of gunnery officers afloat. The possibilities of increased accuracy at long ranges,

and of reasonable accuracy in indirect firing, under conditions of low visibility or complete invisibility (as in the smoke screen), may well exert a profound influence on the whole scheme of battle tactics. There is no doubt that these considerations make the observation aircraft as necessary a part of the modern battleship's gunnery equipment as is the range finder or the maintop.

Courtesy Bureau of Aeronautics, Navy Department.

TORPEDO PLANE AT INSTANT OF DROP

CHAPTER XIV

TORPEDOING AND BOMBING

Torpedoing and bombing are the functions of a single-type aircraft. The characteristics of a bomber necessarily fit it to be a good torpedo plane. The two functions are fully interchangeable. A flight of *VT* planes might attack with bombs, return to the carrier, and proceed to a second attack with torpedoes. The torpedo may be considered in this connection to be a dirigible bomb.

Under certain conditions of clouds bombing cannot be accomplished. The sky is sometimes overcast to such an extent that the view of the earth is lost at a height of one or two thousand feet. Such a condition is quite favorable for torpedo attack whereas bombing is out of the question.

Torpedoing

Whether or not the striking power of torpedo planes will be sufficient to warrant their definite adoption for general naval warfare is uncertain. The chief question in this regard is, of course, whether or not they can demonstrate themselves to be a sufficiently dangerous menace to control the tactics of an enemy fleet; in other words, whether a torpedo-attack plane, properly directed against an enemy battle line in the course of a major engagement, can force the enemy into changes of course which will place him at a disadvantage.

To date torpedo-plane methods have been mostly developed on the target range and have been largely drawn from destroyer practice. In some instances the problem is not exactly similar. Torpedo planes can approach so rapidly and closely before launching that nearly all attacks will be delivered at close range. A much larger percentage of accuracy should be obtained. For this reason aircraft will normally fire at single units in an enemy formation rather than at the formation as a whole. Torpedo planes require a low position, ten to twenty feet, for launching, and a long run gives an excellent opportunity to set the director and to launch as the sighting wires come on.

Salvo methods of torpedo fire are readily adaptable for use with aircraft. It seems, however, that the destructive effect should be distributed as much as possible, at the same time concentrating sufficient strength on each target to insure crippling. Destroyers can be used to complete the destruction. The success of a torpedo-plane attack upon capital ships and aircraft carriers depends primarily upon taking advantage of the element of surprise. To launch its torpedo with effect the plane must fly so low as to become a target for horizontal fire, and many authorities hold that its attack could be frustrated by putting down from the ships' rapid-fire guns, a barrage of waterspouts which, if it did not wreck the airplane altogether, would at any rate spoil its aim and probably deflect the torpedo. An anticipated attack of this nature could be successful only rarely.

Attacks, whenever practicable, are launched down wind, under cover of a smoke screen and, if possible, at the enemy's disengaged side. As in the case

of the policy outlined for bombing, prior to or during a fleet engagement, every effort is made to press home the first attack against the enemy aircraft carrier.

Bombing

The chief of the Bureau of Aeronautics has said:

Potentially, the aircraft bomb, is, I believe, the most serious menace which the surface craft has to face today, not even excepting gunfire. I do not believe with some of our enthusiastic contemporaries, that this necessarily spells the doom of the surface craft as such, but I do believe, and say to you soberly, that the navy which neglects to provide itself with adequate defenses against such attacks from enemy aircraft, to provide its own fleet with this weapon for use against enemy surface craft and bases, cannot but be hopelessly defeated in the event of a major engagement with a navy equipped with this weapon, and that perhaps before the fighting ships have a chance to fire a gun.

The past records of bombing do not give a true indication of its actual possibilities. The percentage of hits which have been made in past tests from wartime bombing altitudes has invariably been small. Bomb sights in use are somewhat inaccurate, and may be compared to the open sights formerly used on guns. Gyroscopic and pendulum stabilized sights are under development, which will be fitted with telescopes. The types of bombs best suited to various types of targets have been well determined. The problem of bombing a moving vessel, which may be zigzagging across wind, is an intricate one. Properly and accurately to determine the course and speed of the target and the force and direction of the wind, and quickly to set the resultant on the sight, bring the sight on the target, and release the bombs, requires experienced, trained, and permanently detailed personnel.

Owing to the low terminal velocity attained by bombs, they must rely upon explosive effect almost entirely for damaging the target. The bombing of obsolete battleships clearly demonstrated that large bombs striking alongside such vessels have sufficient mining effect to endanger their water-tight integrity.

Similar to the fire of big guns, bombs may be dropped in patterns to increase chances of striking the target. The location of bombs in the pattern and dispersion may be varied by varying the location of planes in the formation, and the time of release of each bomb. Considering the probability of hitting and the size of the target, and the number of planes available, pattern size can be determined for each case which will insure the greatest destructive effect. The pattern size as thus determined dictates the arrangement and distance between planes in the bombing formation and the time of release of each bomb.

In cases where no resistance is offered, "spotting bombs" might be used, and the results obtained by previous releases can be observed and corrections made for succeeding releases. Since in time of war a condition of this sort is unlikely, it is essential that bombers approach, release, and escape as promptly as possible. In such a case spotting bombs are dropped and observed before the bomber reaches the objective.

In connection with the discussion of the relative value of aircraft and capital ships, it is interesting to note the views of a naval aviator on the subject. It is not desired to discount the value of bombing from aircraft but to discredit the belief that the air bomber is more than an auxiliary.

It is unfortunate that in many minds the conviction still exists that the sinking of the

bombed vessels conclusively demonstrated the vulnerability of capital ships to aerial-bombing attack. In the majority of cases proponents of this view have failed to realize that the tests conducted were purely of a material nature, and that no tactical considerations were involved. Conclusions based in the slightest degree on the erroneous premises that war conditions were simulated in the attacks are so dangerous as to justify a reopening of the subject.

Aerial operations were conducted from Langley Field, Yorktown, and the Naval Operating Base at Hampton Roads, all within easy flying range of the objectives. Concentration of the bombing forces had begun months before the tests. Detailed plans for the attack were drawn up weeks before the opening of operations. Liaison had been established between the Army and Navy aviation forces. Weather conditions were ideal. Rescue surface craft were in attendance. Targets were stationary. No restrictions were imposed as to the number of runs over the target to determine drift, a privilege taken full advantage of by all operating squadrons. The bombing altitudes averaged 1,500 feet. The use, to frustrate attack, of agencies which might jeopardize the safety of the flying personnel, naturally could not be employed. A consideration of the above conditions, combined with full realization of the difficulties of making hits from the air on, or even close to, ships steaming at twenty-knots at the altitude imposed by anti-aircraft fire, while harassed by enemy combat machines, surely leads to the conclusion that the capital ship still occupies a proper place in the nation's scheme of defense, a place which cannot be filled by the *F-5-L* or the Martin bomber.

General Pershing's opinion that "conclusions, from such trials, that aviation can take the place of either seacoast, or battle fleet protection do not seem to be altogether warranted," substantiates the above.

Also the report of the Secretary of the Navy, dated December, 1924, states in part:

> It is absurd to contend that either the aerial bomb or the submarine torpedo has furnished the effectual answer to the capital ship, for in order to be a capital ship it is essential that it be constructed to resist these new forms of attack. Whenever the submarine torpedo and the aerial bomb become greater sources of danger to a capital ship than gunfire, its armament should be constructed to meet this new menace.

This same report states that, provided modern deck armor protects a ship, "there is little danger that a ship will be sunk by bombs on deck." And further that the modern system of obtaining water-tight integrity effectively protects from the dangers of mining effect of torpedoes and bombs which strike alongside. The older ships to obtain this protection must be sheathed with a "blister."

This report was published after the sinking of the *Washington.*

DIVING ATTACK

The so-called "strafing" form of attack, which is now being used by light fast planes in delivering machine-gun or light bomb attacks against exposed positions on surface ships, is one of the most important forms of fighting tactics of the fleet. In this form of attack the conventional fire-control system breaks down, for the planes approach on irregular courses with rapid and irregular changes in altitude throughout the approach, settling down to a straight flight path in a steep dive for considerably less than ten seconds before actually releasing the bomb. Bombs are released at an altitude of 1,500 feet or less. The speed of approach of the plane, due to its diving approach, is upwards of 200 miles per hour (or about 300 feet per second). This form of attack gives to the plane unrestricted freedom of movement throughout the approach and, until it has reached the final point of release, makes accurate prediction of future positions impossible.

Courtesy Bureau of Aeronautics, Navy Department.

TORPEDO PLANES IN "V" FORMATION

The diving form of attack has been extended to the use of heavier bombs up to 500 pounds weight. We have put into the fleet a new type of two-seater machine to replace the old two-seat observation machines which have been operating from battleships and cruiser catapults. These new machines are fitted to be operated as seaplanes from catapults or as straight landplanes with arresting gear from the decks of carriers.

Smoke Bombs and Screens

Properly included in bombing operations are additional supplementary types of bombing which may be performed by bombing planes and at times by other types of aircraft. These include:

(a) Target illumination (flare dropping).
(b) Gas screen laying.
(c) Smoke screen laying.

These functions are of value primarily during action. Smoke or gas screen laid by bombs or other apparatus can quickly be thrown up at any desired point to shield surface craft exposed to an unusually destructive fire. Smoke screens from aircraft otherwise follow the same general principles as those from surface vessels.

Smoke bombs as experimentaly used in the Navy are small, light bombs of fifty pounds weight, containing about thirty pounds of smoke mixture. The bomb, being lighter than water, eventually bobs up to the surface, and shortly thereafter the slow-match burns through and actuates the starting mixture which fires the main smoke mixture. This burns with an evolution of a dense white smoke for a period of three to five minutes.

Smoke screens are laid by ejecting a chemical from the plane. This chemical may be introduced into the exhaust pipe, in which case it becomes heated and when blown out to the rear forms a rapidly expanding pencil of smoke. This is the most economical use of the chemical, but the screen produced is limited by the expansion of the pencil, which slowly settles toward the water. It has been found advisable to lay the screen at about 100 feet from the water. The screen gradually settles; the expansion of the pencil, however, retains the upper edge of the screen at about the level at which it was first launched. A second form of screen is the smoke curtain, which is produced by forcing the chemical out to the rear of the plane at a velocity equivalent to the air speed of the plane, so that the chemical is at the moment stationary in the air and is not subject to being broken up into small drops by a residual forward motion against the air. The chemical while dropping gradually volatilizes, producing a smoke curtain. This curtain may be laid at the height of 500 feet, and this will serve not only to blanket surface vessels from each other but also for the protection of aircraft approaching at low angles of visibility from the target vessel. The consumption of material in laying this form of screen is, however, some ten times that of the exhaust-pipe type described above. The chemical used in both these screens is a liquid which rapidly volatilizes and picks up moisture from the air, forming a white fog.

The smoke is white and has an excellent obscuring effect. It is fairly persistent but has a tendency to sink quite rapidly. The character of the smoke made indicates that excellent obscuring screens may be laid by a number of planes operating simultaneously.

Courtesy Bureau of Aeronautics, Navy Department.

STANDING SMOKE CURTAIN

The Approach

The introduction of various types of aircraft into the fleet must affect the tactical considerations of the commander in chief in future naval warfare. The force and direction of the wind takes on a new and vital importance, which must be given adequate weight in the selection of courses prior to and during battle. Capital ships carrying aircraft, which are provided with fixed catapult installations on the forecastle, will be most seriously affected. It may be assumed, however, that an active enemy aircraft carrier will select, during the period of operations of planes from the deck, a course either dead into or very close to the wind. The carrying out of torpedo and bombing attacks, therefore, requires a 'cross-wind flight during the near approach, with the attending difficulties of estimating drift and the selection of the point for launching.

While en route from base or carrier to the objective, aircraft should utilize every possible means of concealment. Surprise is the essence of aircraft attack. Where heavy enemy fighting patrols are known to be protecting their fleet, simultaneous attacks from various directions might assist in getting a portion of the attacking force through unobserved. In clear weather, aircraft are less likely to become visible from surface craft if at their ceiling or if very low over the water. The question of audibility may be solved by mufflers, provided they can be developed without serious increase in weight or loss in power. In clear weather aircraft patrols protecting a fleet will probably maintain station at normal bombing altitude, say 10,000 feet. When possible an objective should be approached out of the sun. Fog, broken clouds, rain, and darkness offer a decided advantage for aircraft in attacking an enemy fleet and it is under such cover that the value of these attacks should reach a maximum. In clear weather, torpedo planes should approach low over the water, and bombing planes should approach comfortably below their ceiling.

Courtesy Bureau of Aeronautics, Navy Department

BLINDING THE ENEMY
Planes laying smoke screen around the target

CHAPTER XV

FUTURE OF AVIATION IN WAR

Since the beginning of history man has overestimated his newest accomplishment. This has been particularly true of the means of making war.

Following the Battle of Lissa every ship constructed had a huge projecting ram with which it was expected to sink the enemy. After the first torpedo boats were used in naval warfare it was believed that by using swarms of these small fast crafts the battleship could be swept from the seas. The victory won by the Japanese cruisers at Tsushima caused every nation with maritime ambition to rush the construction of a group of armored cruisers. The success of the German submarines raised the general question as to the advisability of continuing the construction of capital ships. And now, there comes the problem of determining the relative value of aviation.

Is there any reason to believe that aviation will upset the scheme of things that has endured so long? It seems probable that the balance will remain undisturbed. For every means of offense there has been found a means of defense. The ram was defeated by the long-range gun. The torpedo boat was effectively opposed and finally superseded by the torpedo-boat destroyer. The armored cruiser was discarded for its faster and more powerful successor—the battle cruiser, which itself has had to assume a secondary place. The submarine gave way before the fast surface craft armed with the depth charge. By the same precept it does not seem reasonable to believe that the aircraft is capable of the revolutionary powers with which it is sometimes credited by too credulous and impetuous authorities.

That there is a tremendous future for aviation no one will deny, but it must be remembered that aviation is yet only in a formative state.

The 'round-the-world flight by the Army Air Service flyers, spectacular and epochal as it was, did not warrant the conclusion that aviation can at the present time be made an entirely separate and self-sustaining arm of the national defenses. The one outstanding lesson of the achievement was, that it demonstrated conclusively the dependence of the airplane upon surface craft in long-distance work. While the fliers were covering their twenty-odd thousand miles of flight, approximately 87,000 miles of steaming was done by United States naval vessels in helping to make the flight a success. In addition to this was the assistance given by the coast guards and the Japanese Navy.

It has been claimed by those who assert the unlimited possibilities of the aerial bomb that fair success has been had with mediocre sights and that with further development of bombing material, capital ships will be rendered obsolete. Apparently consideration was not given the fact that with increase in efficiency of bombing instruments there will come a corresponding increase in effectiveness of means for combating the bomber, and of armored protection. The present anti-

aircraft guns and fire control of the fleet are tremendous improvement over the war-time guns and methods of firing them.

But this is not the end. Recently an airplane has been sent into the air pilotless, and controlled by radio. The possibilities for destruction presented by the employment of a flight of such craft capable of laying a toxic gas screen are tremendous. The effective use of such an agency might possibly not only render an army or a navy impotent, but might also put to an end the industries so necessary for the maintenance of war. Unprotected, the population itself would be at the mercy of an enemy so equipped. As long, however, as such things are considered beforehand there need be little cause for alarm. The gas attack on the Western Front, which so alarmed the world as to the possibilities of this new weapon, was soon practically neutralized by an antidote—the gas mask. And so it has always been.

From various sources comes the suggestion that a united air force be formed; that all surface war craft be abandoned; and that twenty carriers be provided for use of the air force for overseas missions. The makers of this suggestion do not take into account the fact that the carrier is the most vulnerable of all surface craft to attack from the air. Also, an enemy will refuse to fight according to the plans prepared for him, and may be expected to attack the carriers with destroyers as well as aircraft. If this occurs these destroyers must be met by craft at least as powerful as the destroyer. The enemy will then employ cruisers to press home the attack, and these cruisers must be met by ships capable of successful opposition. By an extension of this process it appears that even if the aircraft with its carrier should become the primary weapon, there would be required for its protection, a fleet of approximately the same dimensions as those now existent.

Great as are the possibilities of aviation there does not seem to be logical reason why it should not be subsidiary, in a military way, to the two primary combatant forces. In time of war there is a battle on land and a battle on sea, each with its attendant struggle for local control of the air, during the battle. Longer control is not necessary. For some years to come it is not possible to conceive of a third and independent battle—a battle in the air. When airplanes become to a reasonable degree independent of surface agencies, such a condition is not only possible but likely. Until that time it seems extremely unwise even to consider casting aside the weapons which have stood the test for so many centuries and accepting in return substitutes, the worth of which has never been proved. And until the fleet is displaced, a strong air force seems more indispensable to it than any other of its auxiliary arms.

General Pershing states that "the air service on land should remain an auxiliary arm," and in his farewell report says:

> We are, therefore, logically forced back to the conclusion that armies must still fight our battles—and to win must overcome the opposing forces. The infantry still remains the backbone of the attack and the rôle of other arms is to help it reach the enemy. All must work in coöperation to that end. The idea that the principles of warfare have changed and that armed contests will be settled in any other way have nothing substantial in our experience to warrant serious consideration.

The analogy in sea warfare is apparent.

A rereading is here recommended of Rear Admiral Moffett's "Missions of Naval Aircraft," given in Chapter IV.

Consider two air fleets, unsupported on the surface, in combat.

One will destroy the other and the surviving air fleet retains its mastery only so long as it is able to stay in the air. If it cannot fall back upon surface ships it will ultimately fall into the sea. With surface ships, however, as an element in the battle, the air force, having gained supremacy in the air gives to its surface ships the immeasurable advantage of pressing on the attack in the air and on the surface to a conclusive victory. Do away with the battleships and you destroy the effectiveness of aviation in defense of our national interests on the high seas.

Again, there is no broad strategic function that aircraft can perform that has not been done since the earliest days of naval warfare. It bears dispatches, it reconnoiters and observes, it carries, it hurls destructive agencies at the enemy. If one gives rein to fancy, it is conceivable, perhaps, that material development may some day permit the construction of aircraft of such size and power that they may be enabled to ride the air as the present surface craft rides the ocean, and even may be relied upon as the first line of battle. The idea is fantastic, to be sure, but even so, the sea cannot be controlled from the air, and control of the sea is always the Navy's mission. Whatever form the weapons take, there still must be battle craft, scouts, dispatch bearers, transports, and supply ships.

Weapons may change—they have been changing since the beginnings of war—and these changes have required changes in the applied tactics of battle, but the fundamental principles of tactics and of strategy remain the same now as they have always been.

CHAPTER XVI

NOMENCLATURE

In making up a glossary of aviation terms, it was desired to attain the following ends:

(a) The inclusion of definitions which would amplify or clarify the text.

(b) The inclusion of important aerodynamical and other terms not explained in the text, which are desirable knowledge to the lay reader and peculiar to aviation.

(c) The exclusion of definitions perfectly obvious from the titular words or phrase, or are common knowledge to everyone.

(d) The exclusion of terms common to aircraft and surface craft, the definitions of which are promulgated by Knight's *Seamanship* or other standard authority.

The definitions are from *Report No. 240*, of the National Advisory Committee for Aeronautics.

Aerodynamics—The branch of dynamics which treats of the motion of air and other gaseous fluids and of the forces acting on solids in motion relative to such fluids.

Aerostat—A generic term for aircraft whose support is chiefly due to buoyancy derived from aerostatic forces. The immersed body consists of one or more bags, cells, or other containers, filled with a gas which is lighter than air.

Aerostatics—The science that treats of the equilibrium of gaseous fluids and of solid bodies immersed in them. As an aeronautic term, it relates to those properties of lighter-than-air aircraft which are due to the buoyancy of the air.

Aerostation—The art of operating aerostats.

Aileron—A hinged or pivoted movable auxiliary surface of an airplane, usually part of the trailing edge of a wing, the primary function of which is to impress a rolling moment on the airplane.

Aircraft—Any weight-carrying device or structure designed to be supported by the air, either by buoyancy or by dynamic action.

Airfoil—Any surface designed to be projected through the air in order to produce a useful dynamic reaction.

Airfoil section (or profile)—A cross section of an airfoil made by a plane parallel to a specified reference plane. A line perpendicular to this plane is called the axis of the airfoil.

Airplane—A mechanically-driven aircraft, heavier than air, fitted with wings, and supported by the dynamic action of the air.

Airplane, pusher—An airplane with the propeller or propellers in the rear of the main supporting surfaces.

Airplane, tandem—An airplane with two or more sets of wings of substantially the same area (not including the tail unit), placed one in front of the other and on about the same level.

Airplane, tractor—An airplane with the propeller or propellers forward of the main supporting surfaces.

Airship—An aerostat provided with a propelling system and with means of controlling the direction of motion. When its power plant is not operating, it acts like a free balloon.

Airship, nonrigid—An airship whose form is maintained by the internal pressure in the gas bags. and ballonets.

Airship, rigid—An airship whose form is maintained by a rigid structure.

Airship, semirigid—An airship whose form is maintained by means of a rigid or jointed keel in conjunction with internal pressure in the gas containers and ballonets. The term "airship" is sometimes incorrectly applied to *heavier-than-air* aircraft either in full or as "ship." This is a slang use of the word and should be avoided.

Air speed—The speed of an aircraft relative to the air.

Air-speed meter; air-speed indicator—An instrument for indicating the speed of an aircraft relative to the air. It is actuated by the pressure developed in a suitable pressure nozzle or against a suitable obstruction and is graduated to give true air speed at a standard air density. The speed indicated by the instrument is termed the "indicated air speed." (The indicated speed is a direct measure of the lift or drag exerted on the airplane at any altitude. Stalling at all altitudes occurs for the same value of the indicated speed.)

Air-speed meter; true air-speed meter—An instrument for measuring the true speed of aircraft relative to the air. The Biram and Robinson anemometers are of this type.

Airway—An air route between air traffic centers which is over terrain best suited for emergency landings, with landing fields at intervals equipped with aids to air navigation and a communication system for the transmission of information pertinent to the operation of aircraft. The term "airway" may apply to an air route for either landplanes or seaplanes or both.

Alarm, gas-cell—A device fitted adjacent to a gas cell, which indicates or warns when a predetermined limiting pressure has been reached in the gas cell. Also called "pressure alarm."

Altigraph—An altimeter equipped with a recording mechanism. Present instruments are of the aneroid type. The chart, driven by clockwork, is usually graduated in feet or meters in accordance with some empirical or arbitrary pressure-temperature-altitude formula. In other words, it is a barograph whose scale is designed to read heights.

Altimeter—An instrument for measuring or indicating the elevation of an aircraft above a given datum plane.

Altimeter, aneroid—An altimeter, the indications of which depend on the deflection of a pressure-sensitive element. The graduations of the dial correspond to an empirical or arbitrary pressure-temperature-altitude formula.

Altimeter, electrical-capacity—An altimeter, the indications of which depend on the variation of an electrical capacity with distance from the earth's surface.

Altimeter, engine—An altimeter for indicating the altitude corresponding to the pressure produced in the intake manifold of a supercharged engine.

Altimeter, optical—An altimeter, the indications of which depend on the manipulation of a suitable optical system.

Altimeter, sound-ranging—An altimeter, the indications of which depend on the measurement of the time required for a sound wave to travel from the aircraft to the earth and back.

Amphibian—An airplane designed to rise from and alight on either land or water.

Anemometer—An instrument for indicating or measuring the speed of an air stream.

Angle, aileron—The angular displacement of an aileron from its neutral position. It is positive when the trailing edge of the aileron is below the neutral position.

Angle, critical—An angle of attack at which the flow about an airfoil changes abruptly with corresponding abrupt changes in the lift and drag.

Angle, downwash—The angle through which an air stream is deflected by any lifting surface of an airplane. It is measured in a plane parallel to the plane of symmetry.

Angle, drift—The horizontal angle between the longitudinal axis of an aircraft and its path relative to the ground.

Angle, elevator—The angular displacement of the elevator from its neutral position. It is positive when the trailing edge of the elevator is below the neutral position.

Angle, landing—The acute angle between the line of thrust of an airplane and the horizontal when the airplane is resting on level ground in its natural position. Also called "ground angle."

Angle, longitudinal dihedral—The difference in angle of wing setting and of stabilizer setting. (This angle is positive when the angle of stabilizer setting, referred to the thrust line, is less than the angle of wing setting.)

Angle, minimum gliding—The acute angle between the horizontal and the most nearly horizontal path along which an airplane can descend steadily in still air when the propeller is giving no thrust.

Angle of attack—The acute angle between the chord of an airfoil and its direction of motion relative to the air. (This definition may be extended to other bodies than airfoils.)

Angle of stabilizer setting—The acute angle between the line of thrust of an airplane and the chord of the stabilizer.

Angle, propeller-blade—The acute angle between the chord of a propeller section and a plane perpendicular to the axis of rotation of the propeller. Usually called "blade angle."

Angle, wing-dihedral or dihedral—The acute angle between the transverse reference line in the wing surface and the lateral axis of the airplane, projected on a plane perpendicular to the longitudinal axis. The dihedral angle is positive when the upper obtuse angle for the two wings is less than 180 degrees.

Apparatus, water-recovery—Apparatus carried on an airship for condensing and recovering the water contained in the exhaust gases of internal-combustion engines in order to avoid the necessity of valving gas as the fuel is consumed.

Aspect ratio—The ratio of span to mean chord of an airfoil; i.e., the ratio of the square of the maximum span to the total area of an airfoil.

Aspect ratio of propeller blade—Half the ratio of propeller diameter to maximum blade width.

Aviation—The art of operating heavier-than-air aircraft.

Balanced surface—A control surface which extends on both sides of the axis of the hinge or pivot in such a manner as to reduce the moment of the air forces about the hinge.

Ballonet—A compartment of variable volume constructed of fabric, or partitioned off, within the interior of a balloon or airship. It is usually partially inflated with air, under the control of valves, from a blower or from an air scoop. By the blowing in or letting out of air, it serves to compensate for changes of volume in the gas contained in the envelope and to maintain the gas pressure, thus preventing deformation or structural failure. By means of two or more ballonets, often used in nonrigid airships, the trim can also be controlled. The ballonet should not be confused with gas cell.

Bay (body parts)—The portion of a face of a truss, or of a fuselage, between adjacent bulkheads or adjacent struts or frame positions.

Blimp—A small nonrigid airship. "Airship" is to be preferred.

Cabane—A framework for supporting the wings at the fuselage; also applied to the system of trussing used to support overhang in a wing.

Camber—The rise in the curve of an airfoil section from its chord, usually expressed as the ratio of the departure of the curve from the chord to the length of the chord. "Upper camber" refers to the upper surface of an airfoil and "lower camber" to the lower surface; "mean camber" is the mean of these two.

Ceiling, absolute—The maximum height above sea level at which a given airplane would be able to maintain horizontal flight, assuming standard air conditions.

Ceiling, service—The height above sea level, assuming standard air conditions, at which a given airplane ceases to be able to rise at a rate higher than a small specified one (100 feet per minute in the United States and England). This specified rate may be different in different countries.

Ceiling, static—The altitude in standard atmosphere, at which an aerostat is in static equilibrium after removal of all dischargeable weights.

Chord (of an airfoil section)—The line of a straight edge brought into contact with the lower surface of the section at two points; in the case of an airfoil having double convex camber, the straight line joining the leading and trailing edges. (These edges may be defined, for this purpose, as the two points in the section which are farthest apart.)

Cone, mooring—The grooved conical member at the extreme bow of an airship which engages with a hollow cone at the top of the mooring mast and provides the coupling between the airship and the mooring mast.

Cord, rip—The rope running from the rip panel to the car or basket, the pulling of which tears off or rips the rip panel and causes immediate deflation.

Decalage—The acute angle between the wing chods of a biplane o multiplane.

Dirigible—That can be diected; steerable; as a dirigible balloon. Its use as a noun to indicate an airship is improper.

Dive—A steep descent, with or without power, in which the air speed is greater than the maximum speed in horizontal flight.

Dope (airplane)—The liquid material applied to the cloth surfaces of airplanes to increase strength, to produce tautness by shrinking, and to act as a filler for maintaining air-tightness.

Dope (airship)—The liquid material applied to rubberized airship fabric to increase gas-tightness. In contrast with airplane dope, it does not cause shrinking.

Dope (pigmented)—An aircraft dope to which a pigment has been added to make an opaque finish, or to protect it from the effects of sunlight.

Drag—The component parallel to the relative wind of the total air force on an aircraft or airfoil. In the case of an airplane, that part of the drag due to the wings is called "wing drag"; that due to the rest of the airplane is called "structural drag" or "parasite resistance."

Duralumin—An alloy of aluminum which is much used in aeronautics, especially for the structure of airships and airplanes. Its chemical composition and physical properties are about as follows:

Copper, 3.5 to 4.5 per cent.
Manganese, 0.4 to 1 per cent.
Magnesium, 0.2 to 0.75 per cent.
Aluminum, 92 per cent, minimum.
Tensile strength, ultimate, 55,000 lbs. per sq. in.
Tensile strength at elastic limit, 30,000 lbs. per sq. in.
Elongation of 2 inches at ultimate strength (test specimen 0.5 inch wide), 18 per cent.
Specific gravity not more than 2.85.

Dynamic factor—The ratio between the load carried by any part of an aircraft when accelerating and the corresponding basic load.

Dynamic (or impact) pressure—The product ½pV squared, where p is the density of the air and V is the relative speed of the air. It is the quantity measured by most air-speed instruments.

Elevator—A movable auxiliary airfoil, the function of which is to impress a pitching moment on the aircraft. The elevator is usually hinged to the stabilizer.

Engine, left-hand—An engine whose propeller shaft, to an observer facing the propeller from the anti-propeller end of the shaft, rotates in a counter-clockwise direction.

Engine, radial—An engine having stationary cylinders arranged radially around a common crankshaft.

Engine, right-hand—An engine whose propeller shaft, to an observer facing the propeller from the anti-propeller end of the shaft, rotates in a clockwise direction.

Engine, rotary—An engine having revolving cylinders arranged radially around a common fixed crankshaft.

Engine, supercharged—An engine with mechanical means for increasing the cylinder charge beyond that normally taken in at the existing atmospheric pressure and temperature.

Envelope—The outer covering of an aerostat, usually of fabric. It may or may not be also the gas container. It may be divided by diaphragms into separate gas compartments or cells, and it may also contain internal air cells or ballonets.

Fin—A fixed surface, attached to a part of the aircraft, parallel to the longitudinal axis, in order to secure stability; for example, tail fin, skid fin, etc. Fins are sometimes adjustable.

Float—A completely inclosed water-tight structure attached to an aircraft in order to give buoyancy and stability when in contact with the surface of the water. In float seaplanes the crew is carried in a fuselage or nacelle separate from the float. The term "pontoon" is now obsolete.

Flying boat—A form of seaplane supported, when resting on the surface of the water, by a hull or hulls providing flotation in addition to serving as fuselages. For the central-hull type, lateral stability is usually provided by wing-tip floats. The term "boat seaplane" is now obsolete.

Fuel (or oil) consumption, specific—The weight of fuel (or oil) consumed per brake horse-power hour.

Fuselage, monocoque—A type of fuselage construction wherein the structure consists of a thin shell of wood, metal, or other material, supported by ribs, frames, belt frames, or bulkheads but usually without longitudinal members other than the shell itself. The whole is so disposed as to carry the stresses to which the structure is subjected.

Gap—The distance between the planes of the chords of any two adjacent wings, measured along a line perpendicular to the chord of the upper wing at any designated point of its leading edge.

Glide—A descent with reference to the air at a normal angle of attack and without engine power sufficient for level flight in still air, the propeller thrust being replaced by a component of gravity along the line of flight. Also used as a verb.

Gondola—The car of an airship. This use of the word is borrowed from the Italian via the German. "Car" is to be preferred.

Gore—The portion of the envelope of a balloon or airship included between two adjacent meridian seams.

Height, pressure—The altitude at which the gas cells of a rigid airship are full, or the gas bag of a nonrigid airship is completely full of gas.

Helicopter—A form of aircraft whose sole support in the air is derived directly from the vertical component of the thrust produced by rotating airfoils.

Horse-power of an engine, rated—The average horse-power developed by an engine of a given type in passing the standard 50-hour endurance test.

Indicator, flight—An instrument in which a lateral inclinometer, a fore-and-aft inclinometer, and a turn indicator are combined to form a compact unit.

Line, mast main mooring—A line led from the main winch of a mooring mast through the mooring attachment at the top of the mast and carried out to a point on the ground well to leeward of the mast. The airship's main mooring line is attached to this line and the airship is hauled to the mast by means of the joined lines. Sometimes called "ground wire"—British.

Loading, power—The gross weight of an airplane, fully loaded, divided by the normal brake horse-power of the engine computed for air of standard density unless otherwise stated.

Loading, wing—The gross weight of an airplane, fully loaded, divided by the area of the supporting surface. The area used in computing the wing loading should include ailerons, but not the stabilizer and elevators.

Longeron—A fore-and-aft member of the framing of an airplane fuselage or nacelle, usually continuous across a number of points of support.

Nacelle—An inclosed shelter for passengers or for a power plant. A nacelle is usually shorter than a fuselage, and does not carry the tail unit.

Ornithopter—A form of aircraft heavier than air, deriving its chief support and propelling force from flapping wings.

Overhang—Used in two senses. (1) One-half of the difference in span of any two main supporting surfaces of an airplane. The overhang is positive when the upper of the two main supporting surfaces has the larger span. (2) The distance from the outer strut attachment to the tip of the wings.

Pancake, to—To level off an airplane at a greater altitude than normal in a landing, thus causing it to stall and to descend on a steeply inclined path with the wings at a very large angle of attack and without appreciable bank.

Pontoon (now obsolete)—See **float.**

Propeller, adjustable pitch—A propeller whose blades are so attached to the hub that they may be set to any desired pitch when the propeller is stationary.

Propeller, controllable pitch or variable pitch—A propeller whose blades are so mounted that they may be turned about their axis to any desired pitch while the propeller is in rotation.

Rope, drag—A long rope which can be hung overboard from a balloon so as to act as a brake and a variable ballast in making a landing. Same as "trail rope" or "guide rope." On airships a similar rope or ropes is used as a haul-down or mooring line by the landing crew. It is usually larger and longer than a regular handling line. Sometimes called "grab line."

Side slipping—Flight in which the laterial axis is inclined and the airplane has a component of velocity in the direction of the lower end of the lateral axis. When it occurs in connection with a turn, it is the opposite of skidding.

Skidding—Sliding sidewise away from the center of curvature when turning. It is usually caused by banking insufficiently, and is the opposite of side slipping.

Skid fin—A fore-and-aft vertical surface, usually placed above the upper wing, designed to provide vertical keel surface and so to increase lateral stability.

Span (airplane)—The maximum distance measured parallel to the lateral axis from tip to tip of an airplane inclusive of ailerons.

Stability, inherent—Stability of an aircraft due solely to the disposition and arrangement of its fixed parts, i.e., that property which causes it, when disturbed, to return to its normal attitude of flight without the use of controls or the interposition of any mechanical devices.

Stability, static—Stability of such a character that, if the airplane is displaced slightly from its normal attitude by rotation about an axis through its center of gravity (as may be done in wind-tunnel experiments), moments come into play which tend to return the airplane toward its original attitude.

Stability, dynamic—Stability of such a character that, if the airplane is displaced from steady motion in flight it tends to return to that steady state of motion, the oscillations due to restoring moments being damped out. (In a general way, the difference between static stability and dynamic stability is that the former depends on restoring moments alone, while the latter includes the action of damping factors.)

Stabilizer—A normally fixed airfoil whose function is to lessen the pitching motion. It is usually located at the rear of an aircraft and is approximately parallel to the plane of the longitudinal and lateral axes. Also called "tail plane."

Stagger—The amount of advance of the leading edge of an upper wing of a biplane, triplane, or multiplane over that of a lower, expressed either as a percentage of gap or in degrees of the angle whose tangent is the percentage just referred to. It is considered positive when the upper wing is forward and is measured from the leading edge of the upper wing along its chord to the point of intersection of this chord with a line drawn perpendicular to the chord of the upper wing at the leading edge of the lower wing, all lines being drawn in a plane parallel to the plane of symmetry.

Stall—The condition of an airplane when from any cause it has lost the air speed necessary for support or control.

Statoscope—An instrument for detecting minute changes of altitude of an aircraft. The indications of the instrument usually depend on small changes of the static pressure of the air.

Step—A break in the form of the bottom of a float or hull, designed to reduce resistance when under way by rapidly reducing the wetted surfaces as speed increases. It also serves to eliminate suction effects.

Streamline—The path of a small portion of a fluid relative to a solid body with respect to which the fluid is moving. The term is commonly used only of such flows as are not eddying, but the distinction should be made clear by the context.

Supercharger—A mechanical device for supplying the engine with a greater weight of charge than would normally be induced at the prevailing atmospheric pressure and temperature.

Supercharger, centrifugal type—A supercharging device equipped with one or more rotating impellers generating centrifugal force which is utilized for the compression and transmission of the air against resistance.

Supercharger, positive-driven type—A supercharger driven at a fixed speed ratio from the engine shaft by gears or other positive means.

Supercharger, rotary-blower type—A supercharging device comprising one or more relatively slow-speed rotors revolving in a stationary case in such a way as to provide a positive displacement.

Supercharger, turbo type—A supercharger driven by a turbine operated by the exhaust gases from the engine.

Surface, control—A movable airfoil designed to be rotated or otherwise moved by the pilot in order to change the attitude of the airplane or airship.

Sweepback—The acute angle between the lateral axis of an airplane and the projection of the axis of the wing on the plane which includes the lateral and longitudinal axes.

Tail slide—The backward and downward motion, tail first, which certain airplanes may be made to take momentarily after having been brought into a stalling position by a steep climb.

Taxi—To run an airplane over the ground, or a seaplane on the surface of water under its own power.

Topping up—The operation of filling up with gas an already partially full aerostat. Also applied to a similar operation with fuel tanks. Incorrectly called "nursing."

Valve, maneuvering—A manually operated valve fitted to the envelope, ballonet, or gas cell of an aerostat for the purpose of releasing gas or air from within the envelope or gas cell when desired.

Venturi, speed-indicating—A Venturi tube may be combined with a Pitot tube or with a tube giving static pressure to form a pressure nozzle which may be used to determine the indicated speed of an aircraft through the air. The pressure difference is measured by a suitable gauge.

Venturi tube—A short tube with flaring ends and a narrow or constricted section between them, into which a side tube opens. When fluid flows through the Venturi, there is a reduction of pressure in the constricted section, the amount of the reduction being a function of the velocity of flow.

Vertimeter—A device for indicating the rate of rise and fall of an aerostat, usually a special form of statoscope. A rate-of-climb meter serves the same purpose, although of a different form.

Warp—To change the form of a wing by twisting it. Warping is sometimes used to maintain the lateral equilibrium of an airplane.

Washin—Permanent warping of the wing which results in an increase in the angle of attack near the tip.

Washout—Permanent warping of a wing which results in a decrease in the angle of attack near the tip.

Weight, empty—The structure, power plant, and fixed equipment of an aircraft. Included in this fixed equipment are the water in the radiator and the cooling system, all essential instruments and furnishings, fixed electric wiring for lighting, heating, etc. In the case of the aerostat the amount of ballast which must be carried to assist in making a safe landing must also be included.

Weight per horse-power—The dry weight of an engine divided by the rated horse-power.

Wind tunnel—An elongated chamber, usually a tube divergent at the ends, through which a steady air stream may be drawn or forced. Models of airfoils, of aircraft, or of propellers may be placed in the middle portion of the tunnel, called the experiment chamber or working section, and supported by suitable balances placed outside the air stream, so that the forces, moments, etc., due to the moving air may be measured.

Wing-heavy—The condition of an airplane in which (in normal flight) there is a tendency for the right (or left) wing to drop, if the lateral control is released, i.e., the condition in which the pilot has to exert a lateral force on the control stick to keep the lateral axis horizontal.

Wing rib—A fore-and-aft member of the wing structure of an airplane, used to give the wing section its form and to transmit the load from the fabric to the spars.

Wing spar—The principal transverse structural member of the wing assembly of an airplane.

Zoom—To climb for a short time at an angle greater than that which can be maintained in steady flight, the airplane being carried upward at the expense of its kinetic energy. This term is sometimes used as a noun, to denote any sudden increase in the upward slope of the flight path.

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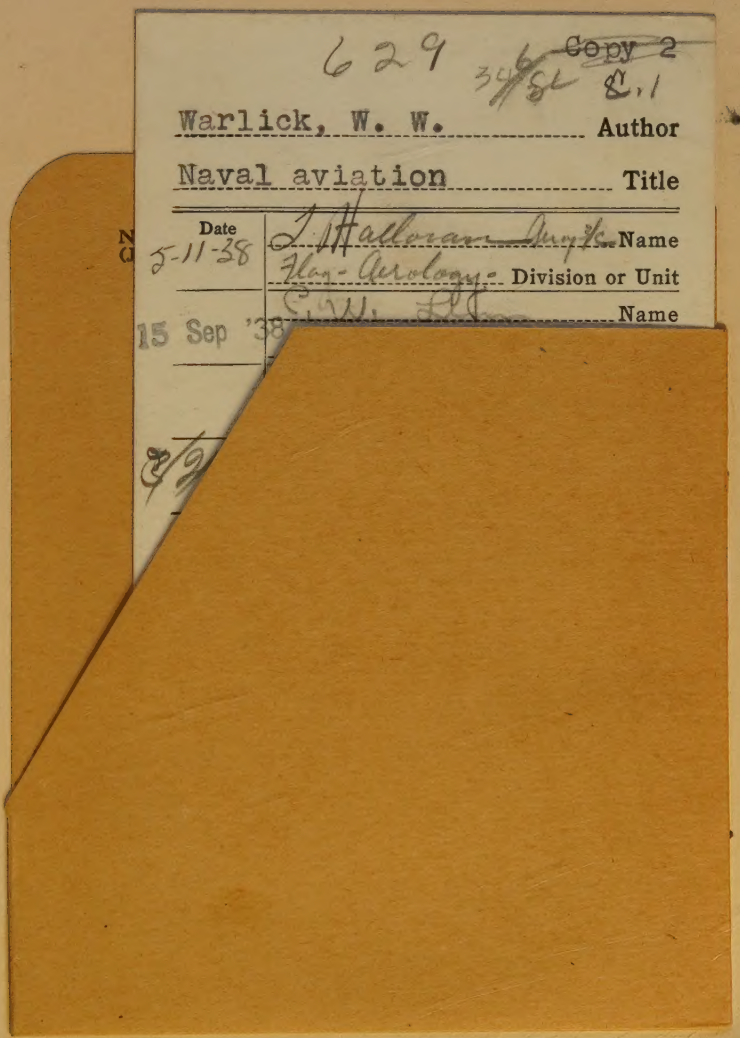
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